

# Communication Media Choice in Globally Distributed Software Projects

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Tuomas Jaanu

# Communication Media Choice in Globally Distributed Software Projects

**Tuomas Jaanu**

A doctoral dissertation completed for the degree of Doctor of Science (Technology) to be defended, with the permission of the Aalto University School of Science, at a public examination held at the lecture hall T2 of the school on January 12th 2018 at noon.

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**Abstract**

The topic for this thesis is to study the communication media choice in globally distributed software projects. This thesis is based on both qualitative data collected from interviews of software professionals working in globally distributed software projects, as well as analysis of communication patterns in such projects. The approach is to evaluate perceived communication media choice and use to understand how communication media is chosen in globally distributed software projects, how the choice affects the projects and teams, and whether particularly good media choice could lead to better outcomes in distributed projects. This thesis will also analyse the communication media choice and use using media choice theories, most notably Media Synchronicity Theory, and assess if the findings are aligned with the predictions of the theory as well as previous research on the area.

Main findings in this thesis includes the assessment of which communication media are most commonly used in globally distributed software projects, for which tasks, and by whom. The findings also highlight important organizational factors and individual preferences on communication media use, such as language skills and organizational role, which affect both preference to use a particular communication media as well as the satisfaction and efficiency in using the tool. Furthermore, the findings are brought into a larger context in discussion about the relationship between communication tool choice and project satisfaction and communication efficiency.

This thesis aims to provide both practical advice for globally distributed software teams and theoretical guidelines for future research. The contribution for practitioners of this research is to organize and make visible all the factors affecting media choice, and by raising awareness of such factors, aim to improve the overall quality, satisfaction and performance of globally distributed software teams. For future research, this research contributes by both providing confirming evidence on some of the core propositions of Media Synchronicity Theory, as well as pointing out additional factors less pronounced in the current research.

**Keywords** global software development, media choice, communication, software projects

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**Tiivistelmä**

Tämän väitöskirjan tutkimusaiheena on viestintävälineen valinta maailmanlaajuisesti hajautetuissa ohjelmistoprojekteissa. Tutkimus pohjautuu sekä laadulliseen haastattelututkimukseen, jossa on haastateltu hajautetuissa ohjelmistoprojekteissa toimivia ohjelmistotalon ammattilaisia, sekä hajautettujen projektien viestintävälineiden käytön analysointiin. Ongelmaa on lähestytty selvittämällä viestintävälineen valinnan ja käytön kokemuksia, sitä, miten viestintäväline hajautetuissa ohjelmistoprojekteissa valitaan, miten valinta vaikuttaa projekteihin ja projektitietoihin, sekä johtaako onnistunut viestintävälineen valinta parempiin lopputuloksiin hajautetuissa projekteissa. Väitöskirjassa tarkastellaan viestintävälineiden valintaa ja käyttöä tukeutuen viestintävälineen valintateorioihin, ennen kaikkea Media Synchronicity -teoriaan, ja arvioidaan onko tutkimustulokset linjassa teorian väittämien ja aiemman tutkimuksen kanssa.

Väitöskirjatutkimuksen keskeiset tulokset liittyvät selvitykseen siitä, mitä viestintävälineitä hajautetuissa ohjelmistoprojekteissa on käytössä, mihin tehtäviin niiden käyttö liittyy, ja ketkä näitä välineitä käyttävät. Tulokset osoittavat organisaation ja yksilötason piirteiden, kuten kielitaidon ja työroolin, vaikutuksen viestintävälineiden valintaan ja käyttöön. Lisäksi arvioidaan viestintävälineen valinnan yhteyttä työtyytyväisyyteen ja viestinnän tehokkuuteen.

Tämän väitöskirjan tavoitteena on antaa sekä käytännön neuvoja hajautetuille ohjelmistoprojekteille että ohjata tulevaa tutkimusta aiheeseen liittyen. Hajautetuissa ohjelmistoprojekteissa työskenteleville tämä tutkimus pyrkii tarjoamaan jäsennehtyä tietoa kaikista viestintävälineen valintaan liittyvistä seikoista, ja siten edistää hajautettujen projektien yleistä laatutasoa, työtyytyväisyyttä ja työn tuottavuutta. Jatkotutkimuksen kannalta tämän työn keskeistä antia on vahvistus Media Synchronicity -teorian keskeisten osa-alueiden väittämille sekä tunnistaa vielä puuttuvia osa-alueita teoriasta.

**Avainsanat** hajautettu ohjelmistotuotanto, viestintävälineen valinta, viestintä, ohjelmistoprojektit

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Many people have participated in this research, by allowing us to interview them and to explore their projects and teams. I would like to thank all our industrial partners for their support for our research, as well as support from Finnish Funding Agency for Technology (TEKES) for the research project.

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Helsinki, Finland, October 25, 2017,

Tuomas Jaanu





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# List of Publications

This thesis consists of an overview and of the following publications which are referred to in the text by their Roman numerals.

**I** Tuomas Niinimäki, Arttu Piri and Casper Lassenius. Factors Affecting Audio and Text-based Communication Media Choice in Global Software Development Projects. In *Fourth IEEE International Conference on Global Software Engineering*, Limerick, Ireland, pp. 153–162 , August 2009.

**II** Tuomas Niinimäki, Arttu Piri, Casper Lassenius and Maria Paasivaara. Reflecting the Choice and Usage of Communication Tools in GSD Projects with Media Synchronicity Theory. *Journal of Software Maintenance and Evolution: Research and Practice*, Volume 24, Issue 6, pp. 677–692, October 2012.

**III** Tuomas Jaanu, Maria Paasivaara and Casper Lassenius. Effects of Four Distances on Communication Processes in Global Software Projects. In *Sixth International Symposium on Empirical Software Engineering and Measurement*, Lund, Sweden, pp. 231–234, September 2012.

**IV** Tuomas Niinimäki and Casper Lassenius. Experiences of Instant Messaging in Global Software Development Projects: A Multiple Case Study. In *Third IEEE International Conference on Global Software Engineering*, Bangalore, India, pp. 55–64, August 2008.

**V** Tuomas Niinimäki, Maria Paasivaara and Casper Lassenius. Near-

Synchronicity and Distance: Instant Messaging as a Medium for Global Software Engineering. In *Seventh IEEE International Conference on Global Software Engineering*, Porto Alegre, Brazil, pp. 149–153, August 2012.

**VI** Tuomas Niinimäki. Face-to-face, Email and Instant Messaging in Distributed Agile Software Development Project. In *International Workshop on Tool Support Development and Management in Distributed Software Projects*, Helsinki, Finland, pp. 78–84, August 2011.

# Author's Contribution

## **Publication I: “Factors Affecting Audio and Text-based Communication Media Choice in Global Software Development Projects”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design, data collection and preliminary analysis was done in collaboration with all authors and Maria Paasivaara.

## **Publication II: “Reflecting the Choice and Usage of Communication Tools in GSD Projects with Media Synchronicity Theory”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design, data collection and preliminary analysis was done in collaboration with all authors.

## **Publication III: “Effects of Four Distances on Communication Processes in Global Software Projects”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design, data collection and preliminary analysis was done in collaboration with all authors and Arttu Piri.



#### **Publication IV: “Experiences of Instant Messaging in Global Software Development Projects: A Multiple Case Study”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design, data collection and preliminary analysis was done in collaboration with all authors, Maria Paasivaara and Arttu Piri

#### **Publication V: “Near-Synchronicity and Distance: Instant Messaging as a Medium for Global Software Engineering”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design, data collection and preliminary analysis was done in collaboration with all authors and Arttu Piri.

#### **Publication VI: “Face-to-face, Email and Instant Messaging in Distributed Agile Software Development Project”**

The author of this thesis was the principal author, and was responsible for the detailed data analysis and writing the article. Overall research design and data collection was done in collaboration with other researchers participating in the research project.

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# 1. Introduction

The topic for this thesis is communication media choice and use in globally distributed software projects. Following chapters outline the motivation and background for the research presented in this thesis as well as presents the formulation of the research problem for this thesis.

## 1.1 Background and motivation

The overall trend in software companies since the 1990s has been to out-source and offshore software development [47]. There have been multiple drivers for this development: significantly lower software development costs in developing countries, the availability of trained workforce, ability to flexibly build and adapt new virtual organizations, necessity of getting closer to customers in emerging markets, and the possibility of around-the-clock development [12, 47].

Distributed software development does not come without cost. Working on software projects even on collocated teams is difficult due to the properties of computer software itself, such as its invisibility, constant change, ambiguously defined scope and the large amount of tacit information on the software product and development process [8]. Companies and teams developing software face many problems and challenges during software projects, many of which are not of technical nature [14]. It is also known that software development involves a large amount of communication and collaboration between different stakeholders and within the software development team itself: communication within the software development team is one of the critical success factors for software projects [14, 55].

Earlier research has shown that communication frequency heavily depends on the distance between communicating parties [3]. Thus, while communication is a challenge even in collocated software development

settings, it becomes even more problematic in global software development (GSD) projects, in which software is developed in physically separate locations [45, 44]. In GSD projects, challenges in communication have significantly slowed down the overall project progress [44]. In addition to physical distance, also other issues, such as cultural and time zone differences, and infrastructure availability contribute to the challenges in communication [46]. Earlier research reports that 74% of the problems in distributed projects were caused by "communication and contacts". These problems were caused by two major factors: physical distance and cultural differences including language barriers. It was often the case, that language skills were so low, that fluent conversation became impossible, most notably over verbal communication media, such as teleconferencing. [54]

To overcome the distance, and to augment the physical, face-to-face communication, GSD projects need to use some communication media, such as the telephone, teleconferences, electronic mail and instant messaging [44]. All these media have different histories, and thus different conventions and properties. Some communication tools have been around for a longer time, such as email, which has been used in global organizations for decades [91], or telephones and teleconferences, which are also used to coordinate and collaborate over distance in globally distributed projects [37].

Recently, a range of new computer mediated communication tools, such as instant messaging [39, 43, 64] and voice-over-IP (VoIP) applications [85] have become more and more commonplace in global organizations and especially in global software development projects.

There are several theories modeling the proper selection of communication tools for given tasks. Media Richness Theory (MRT) [15] builds on the concept of *richness* of a medium: richer media should be used for tasks of higher uncertainty and complexity, while simple and uncomplicated tasks should be dealt with using leaner communication media. Social presence theory [89] emphasizes the medium's capability of creating a feeling of being together: social presence theory claims that the communication has more effect when the sense of togetherness is higher between communicative parties, and that communication tools vary in their capability to create togetherness. Media Synchronicity Theory (MST) [22, 20] provides a more versatile view on communication, and is based on two communicative processes: sharing information and building common understanding.

This thesis investigates communication media choice in globally dis-

tributed software projects and the effect of media choice to communication efficiency, satisfaction and project outcomes. Altogether this thesis includes a total of 79 interviews from 12 software projects in three different companies<sup>1</sup>. In addition to qualitative interview data, we collected quantitative data on communication and individual interaction in one distributed project, collecting their face-to-face communication patterns as well as email and instant messaging logs. As the methods used in this thesis are majorly qualitative in nature, it does not aim to conclusively assert or evaluate the findings nor the assumptions of the selected theoretical framework, but rather aim to provide and disseminate evidence for and against the media synchronicity theory and in the effects of media choice in global software development projects in general.

## 1.2 Research problem

The goals of this research are derived from the observed gap between practice and theory. While there are several theories modelling media choice process, and there are studies describing communication in distributed software teams, we wanted to explore how media choice is done in practice, and if proper media choice improves software project outcomes. Therefore, the research problem for this thesis is: *How is communication media chosen in globally distributed software projects?*

## 1.3 Contributions

Tuomas Jaanu<sup>2</sup> is the first author in all research articles included as a part of this dissertation. The original research approach was designed as well as data collection and analysis was designed and executed in collaboration with other members of the research group. Tuomas Jaanu was independently responsible of the specific research approach and research questions for the included studies, selection and application of research methodologies, and conducted more detailed qualitative analysis on the collected data for the included articles. Overall data collection and re-

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<sup>1</sup>The number of companies presented here is the number of on-site companies, i.e. the companies owning the software projects. Some of the studied projects used external contractors as well as offshoring companies, which are not counted towards this number

<sup>2</sup>Tuomas Jaanu was known as Tuomas Niinimäki until October 2011



search design was done in co-operation with other researchers in the Software Process Research Group (SPRG) of Aalto University.

## **1.4 Thesis structure**

In chapter 2, the theoretical framework used in this thesis and related theories are presented.

Chapter 3 examines the previous work in the fields of global software development research and results for studies investigating media choice theories, specifically in context of globally distributed virtual teams.

Chapter 4 describes the research methods used in this thesis and in research articles included as a part of this thesis.

Chapter 5 reflects the results from the research articles, and provides answers to each of the research questions.

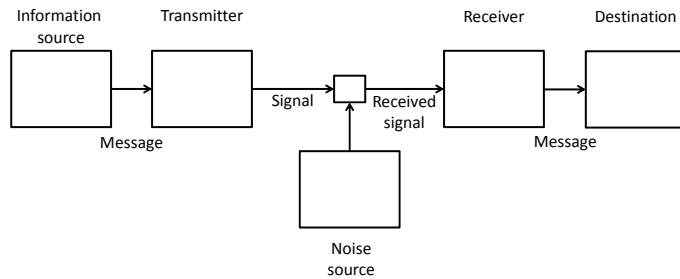
Chapter 6 has the discussion about the limitations of this study.

Chapter 7 summarizes the discussion around research questions in order to answer the research problem, and discusses about the implications to theory and practices based on results. Also directions for future work and research on this area are discussed in this chapter.

## 2. Theoretical background

This section introduces the theoretical background used for this thesis. In this chapter, we introduce the media choice theories, most notably Media Richness Theory (MRT) [15] and Media Synchronicity Theory (MST) [22, 20].

### 2.1 Communication Theory



**Figure 2.1.** Shannon's diagram of a general communication system, from [87]

Shannon's seminal work on electronic communication and information theory [87] lays basis on the study of computer-mediated communication. The model presented by Shannon describes the basic components of a communication system (see Figure 2.1), and while the theory focuses on more low-level, physical aspects of a communication system, these components and concepts remain the same when communication is studied on higher level.

Shannon and Weaver extended the original idea later, by extending the discussion on communication from low-level, electrical presentation of information as a signal into higher level of semantic interpretation of mes-

sages [88]. The central focus in his theory is that communication is any act in which one mind may affect another. Shannon and Weaver categorize communication problems into three levels:

LEVEL A. The technical problem - How accurately can the symbols of communication be transmitted?

LEVEL B. The semantic problem - How precisely do the transmitted symbols convey the desired meaning?

LEVEL C. The effectiveness problem - How effectively does the received meaning affect conduct in the desired way?

In the model, communication is presented as an act of information transfer between two endpoints: information source and destination. The technical problem — transfer of information between these two endpoints — can be divided into five distinct steps[88]:

1. Desired piece of information from the information source is selected and encapsulated in a message
2. Transmitter encodes the message into a signal and transmits it over a channel (a medium)
3. A noise source may introduce noise to the signal
4. Receiver decodes the received signal (original signal with noise) and decode it into a received message
5. Destination interprets the received message, and based on the interaction the message may or may not have an effect

Weaver argues that both the semantic problem (level B) and effectiveness problem (level C) inherit the limitations from the technical problem (level A): as the message is transferred only through the channel, any limitations in either encapsulating, encoding, decoding or interpreting the message will affect both effectiveness of communication as well as the semantic interpretation of the message [88].

However, the model presented is simplified in the sense that its view of communication as series of transmissions — with each transmission to be "perfect", ie. unambiguous and concise — and thus neglecting both the context of communication and participants as well as the properties and social norms of the channel (or communication medium) used in the communication. Therefore, while the mathematical model presented by Shannon provides an interesting basis for studying communication, in order to study mediated communication, both the media properties and communication context must be understood.

## 2.2 Media Choice

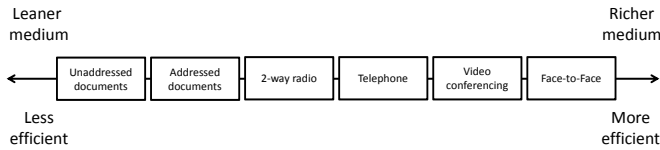
In many cases, there are several ways (media) of delivering the same message. These typically differ in the extent to which they restrict or constrain the possibilities to express, deliver and present the idea. Such constraints can either be due to the medium's ability to address different human sensory systems (e.g. audio-only vs. text-only), due to its ability to represent the intended message (e.g. availability of special characters for mathematics or the resolution for graphics), to the message producing capabilities of the medium (e.g. the possibility to use moving images), and to the social "constraints" of a given medium (e.g. media availability).

Theoretical knowledge on choosing, using and evaluating communication and collaboration tools for teams aims at modelling, refining and generalizing the findings and results from research on communicative and collaborative activities within and between teams. Specifically, media choice theories try to explain why certain tools should be used for certain tasks or activities. There are several existing theories modelling the factors affecting media choice, and suggesting the rationale for choosing the right medium for a message.

## 2.3 Media Richness Theory

Media Richness Theory (MRT) [15] attributes a single property, richness, to a communication media. Richness of a medium is a function of "the ability of information to change understanding within a time interval" [16]. A medium is considered richer the more communication channels and feedback it provides, the more targeted the message is, and if the language

conveys shared meanings and is easily understood by all communicating parties (see Figure 2.2).



**Figure 2.2.** Richness of media, adapted from [16]

MRT suggests that different professional tasks are completed more efficiently when task properties and media richness matches. The task properties presented by media richness theory are task equivocality and task uncertainty. With tasks of equivocality, a group has to agree on correct interpretation of the situation. With uncertain tasks, the group does not possess all necessary information about the situation. According to the theory, tasks with high equivocality and uncertainty should be channelled via richer media, while unequivocal and certain tasks can be accomplished better with leaner medium. [15, 16]

MRT [15] implies that the sender ideally should use the richest possible medium for equivocal and uncertain messages. The theory also posits that richest medium possible will provide the best end results and the most efficient and effective communication [15]. In reality, however, this is often not possible. In these cases, the sender should consider the purpose and intent of the message, and select the appropriate medium accordingly. On the other hand, it is also understood that a richer medium typically requires much more involvement and attention from audience [59, 81].

MRT assumes that a single "richness" value can be assigned to a medium. Earlier work has reported, that task-technology fit is more complicated than what MRT suggests [18]. MRT also neglects the social context of the communication, as the view on communication and collaboration taken by media richness theory is task-oriented, taking only the medium and the message into account [23]. In many cases, when working in a distributed cross-functional team, it is necessary to understand the context of communication, the differences in participants' backgrounds, experience and culture, as well as the individual preferences on communication [22].

In previous work based on MRT, media choice and actual media use is

often somewhat disconnected. Many earlier studies (e.g. [84]) focus on the media choice process, but the actual statements on media use and the effect on task performance based on media richness theory are often left untested or inconclusive [21]. Study on communication media choice by managers has concluded that managers prefer to use rich media for ambiguous communication, and leaner media for unequivocal communication [17]. Overall team performance and communication performance has been reported to correlate positively when using telephone, and negatively, when using video conferencing [62], a result contradicting with media richness theory.

## 2.4 Media Synchronicity Theory

Media Synchronicity Theory (MST) [22] was built on further research on the MRT, to overcome the limitations of MRT. Instead of using a concept of media richness, MST uses a concept of media synchronicity to assess different communication media. Dennis and Valacich define media synchronicity as "the extent to which a communication environment encourages individuals to work together on the same activity, with the same information, at the same time; i.e. to have a shared focus" [22]. As a contrast to MRT, MST does not argue that maximizing media synchronicity always improves the communication effectiveness. Instead, MST suggests that effective media use requires a match between media capabilities and fundamental communication processes needed to perform the task. To understand the requirements for communication in a given context, MST uses two communication processes: conveyance — the exchange of information, and convergence — the development of shared meaning for the information. The ability of a communication medium to support either of these processes are based on the characteristics of the communication tool in question. [22]

MST is a theory with two different versions. In next chapters, we present the original 1999 version of the theory [22], and after that, the revised theory from 2008 [20].

### 2.4.1 Media capabilities

Original MST uses following five capabilities to evaluate the ability of a communication medium to support conveyance and convergence. The

ability of a communication medium to support either of these processes are based on the characteristics of the communication tool in question. MST defines these five capabilities: immediacy of feedback, symbol variety, parallelism, rehearsability and reprocessability.

*Immediacy of feedback* represents the extent to which the communication tool allows communicating parties to be aware whether the message was received, understood and acted upon by the recipients. As the tool provides support for feedback from the recipient to the sender, it helps the sender (the source of information) to verify and evaluate the reception of the message. Through feedback it is possible for the recipient to notify the sender about ambiguous issues in the message, and for the sender to reply with clarifications and to provide additional information. The extent to which a tool provides possibilities for feedback — and the latency between a message and the feedback for the message — define much of the suitability of the communication tool for tasks requiring tight and synchronous collaboration.

Communication media can be divided into two main categories based on the immediacy of feedback they provide: synchronous communication media requires both the sender and the recipient of the communication to be engaged in the communication at the same time, while asynchronous media allow the communicating parties independence to communicate at different times.

*Symbol variety* determines the possibility to express various messages and meanings over a medium. The concept of symbol variety is closely related to the concept of medium richness, a property defined in the media richness theory. However, the symbol variety of a communication medium extends the concept of richness in the sense that it also focuses on the variety of symbols within a single medium rather than looking at the variety of additional cues available for conveying a message through the communication tool. The effect of a high symbol variety in communicative processes is to make the expression of complex ideas easier, as the medium with the higher symbol variety provides more "building blocks" for constructing the message.

The possibility and ease of expressing different messages with a communication tool depends on the symbol variety of the communication medium. Higher symbol variety increases the scope of the communication tool, but can also make comprehending the message more difficult, as a high number of symbols increases the number of possible interpretations.

*Parallelism* refers to the number of simultaneous conversations that can co-exist effectively. Communication media with low parallelism allow only one active conversation at a time, which may require the full attention of the communicating parties. An example of such medium is telephone: in general, an individual may attend only one phone call at once, and generally within one phone call, only one participant may be talking, regardless of number of participants in the phone call. Medium with higher parallelism allow multiple conversations at the same time. For instance, discussion forums allow one person to start one topic, another individual might be starting another, unrelated topic at the same time, and third person might be responding to an existing discussion topic, all at the same time.

*Rehearsability* is a characteristic of a communication medium that allows the sender time to review, rethink and rephrase the message before sending it to the recipient. Ability to review and modify the message before publishing it helps the sender to fine-tune the expression, and gives extra time to ensure that the message is properly expressed, understandable and consistent.

*Reprocessability* of messages from a communication medium is a characteristic related to rehearsability, but addresses the issue of managing the messages during or after the communication has occurred. Reprocessability represents the extent to which the sender or the recipient is able to revisit the communication event at a later point of time. A communication medium with high reprocessability provides its users with means to review the contents and participants of the communication, to process the communicated information, and to relate the message to earlier communications and other sources of information. The ability to do so helps the communicating party to form a better understanding of the nature and meaning of the communication, to acquire and review additional information required to comprehend the intended message, and to reorganize the information into more suitable form for further use. Reprocessability further enhances the ability of a participant in the communication to explain the contents of the communication to other parties, who have not taken part in the original communication event.

#### **2.4.2 Communicative processes**

MST defines two communication processes: conveyance — the exchange of information, and convergence — the development of shared meaning



for the information.

Conveyance is the process of sharing and exchanging information on the task at hand. The conveyance focuses on collecting and combining information from various sources, with the goal of gathering as much relevant information as possible and distributing it to all relevant stakeholders. At this stage, communicative parties have access to the information, but may be unaware of interpretations of that information — whether it is their own interpretation or the interpretation of others. For instance, becoming aware of whether a task is completed by means of exchanging information from peers, can be considered conveyance, but as such mere awareness of task completion does not induce common understanding of which actions are possible now that the task has been completed.

Convergence is the process in which the information gets refined into shared understanding. This process involves participants to share their interpretation of the information they possess, with a goal to converge into a common interpretation of the available information. Even if individual conclusions of the information differ, the process of convergence improve each participants' understanding of the topic, as well as make it more probable that various aspects of the topic have been considered more thoroughly.

**Table 2.1.** Communicative processes and media capabilities, adapted from [22]

	Conveyance	Convergence
Immediacy of feedback	Low	High
Parallelism	High	Low
Symbol variety	Low	High
Rehearsability	High	Low
Reprocessability	High	Low

MST suggests that convergence process benefits from media synchronicity, while conveyance process does not [20]. The ability of a communication medium to support either of these processes are based on the characteristics of the communication tool in question. Table 2.1 presents the ability of each five capabilities to support conveyance and convergence. Table 2.2 summarizes the evaluation of five capabilities on commonly used communication media [22].

**Table 2.2.** Capabilities of communication media common in GSD projects, adapted from [22]

	Feedback	Symbol Variety	Parallelism	Rehearsability	Reprocessability
Face-to-face	high	low-high	low	low	low
Video conference	medium-high	low-high	low	low	low
Telephone	medium	low	low	low	low
Electronic mail	low-medium	low-high	medium	high	high
Chat (IM)	medium	low-medium	medium	low-medium	low-medium
Issue tracker	low	low-high	high	high	high

While many tasks involve both conveying information and converging on shared meanings, a single communication media is often able either to convey information or to support the convergence of understanding. The media synchronicity theory suggests, that multiple communication media should be thus used when performing a complex task; multiple communication media differ in their support for these two processes and thus provide support for both conveyance and convergence as needed by the task.[22]

### 2.4.3 Communication media choice and communication performance

Media synchronicity theory [22] sets forth nine propositions related to communication performance:

1. For group communication processes in which convergence is the goal, use of media providing high synchronicity (high feedback and low parallelism) will lead to better performance.
2. For group communication processes in which conveyance is the goal, use of media providing low synchronicity (low feedback and high parallelism) will lead to better performance.
3. A medium's symbol variety will only affect performance when a needed symbol set is not available.
4. Use of media provided higher rehearsability will lead to better performance.
5. For group communication processes in which conveyance is the goal,

use of media providing higher reprocessability will lead to better performance.

6. Established groups with accepted norms will require less use of media with high synchronicity (high feedback and low parallelism) than groups without such norms.
7. As a given group works and develops over time, it will require less use of media with high synchronicity (high feedback and low parallelism).
8. Newly formed groups, groups with new members, and groups without accepted norms for production, group well-being, or member support will require more use of media with high synchronicity (high feedback and low parallelism).
9. Newly formed groups, groups with new members, and groups without accepted norms will engage in more socially related communication activities than established groups and thus prefer the use of media providing symbols sets with greater social presence.

In this thesis, the above nine propositions are used to evaluate whether media choice is successful or aligned with MST.

## 2.5 Revised Media Synchronicity Theory

Revised MST sees communication through same two communicative processes as the original MST: conveyance and convergence.

In revised MST, *conveyance* is defined as "the transmission of a diversity of new information — as much new, relevant information as needed—to enable the receiver to create and revise a mental model of the situation. Individuals participating in conveyance processes engage in substantial information processing activities so that a potentially large, diverse set of information can be exchanged in a variety of information formats. Individuals participating in conveyance processes will often require time to perform information processing—the cognitive processes necessary to analyze the information, make sense of it, and build their mental models." [20]

By *convergence*, they mean "the discussion of preprocessed information

about each individual's interpretation of a situation, not the raw information itself. . . . Convergence typically needs rapid, back and forth information transmission of small quantities of preprocessed information. Convergence can require less information processing than conveyance when it focuses on the verification of and/or modest adjustments to existing mental models." [20]

*Transmission velocity* is the speed at which a medium can deliver a message to intended recipients. Media that are high in transmission velocity allow messages to reach the recipients as soon as they are sent. Therefore, messages spend less time in transmission. Faster transmission velocity also allows a message to be responded to faster, meaning that the communication can approach continuous exchange with improved coordination and quicker feedback between individuals. [20]

*Parallelism* is the number of simultaneous transmissions that can effectively take place. Parallelism impacts the synchronicity of a medium by increasing the number of concurrent transmissions and by supporting multidirectional communication. One user can start discussion on one topic while at the same time another user starts a discussion on a different topic, and a third user starts a third unrelated topic. These three discussions can become intertwined, so that rather than focusing on one topic at a time, the discussion interleaves messages. [20]

*Symbol sets* are the number of ways in which a medium allows information to be encoded for communication. Symbol sets may affect the synchronicity supported by a medium in two fundamental ways. First, the time and effort required to encode and to decode a message using a specific symbol set may impose production costs and processing delay costs. Second, some information may be more precisely encoded and decoded in one symbol set than another. Individuals can more effectively and efficiently encode and decode information when the symbol set matches the needs of the message. [20]

*Rehearsability* is the extent to which the media enables the sender to rehearse or fine tune a message during encoding, before sending. [20]

*Reprocessability* is the extent to which the medium enables a message to be reexamined or processed again, during decoding, either within the context of the communication event or after the event has passed. [20]

In addition to communicative processes and media properties, media use and context does affect the outcome of media use. In revised MST, this is included in the form of appropriation factors. Appropriation factors

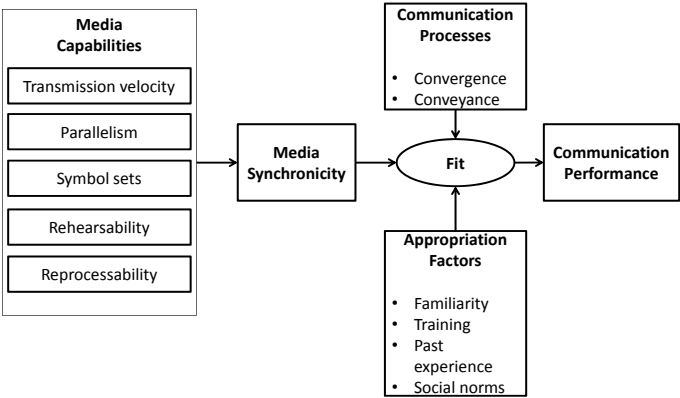
aim at taking into account who and in which circumstances the media is used, and how that might affect communication performance. Such factors include familiarity with the tool, how commonly the media is used, as well as how easy it is to use and access the communication medium. [20]

## **2.6 Comparison of original and revised Media Synchronicity Theories**

The original MST [22] was refined in 2008 [20] by Dennis, Fuller and Valacich. This thesis and research articles related to this thesis use the theory as defined in the original 1999 research article [22]. At the time research was designed and while most of the data was analysed, the new revised version of the theory was not yet published. In general, we believe the differences between original and revised version of the theory have minimal effect on the analysis results or the conclusions. However, in this chapter, we go through the core concepts on both versions, and provide discussion about the changes in revised theory. See chapter 6.5 for discussion about the potential effect of results and reflection of the revised MST on the interpretation of the results.

Conceptually, the revised version explicitly mentions it does not aim at predicting the choice or use of specific communication media for any given context, but the successfulness and appropriateness of use of specific communication media in certain context. This is an important assertion, as most messages can be communicated over several media — and it often happens, that the most appropriate media is not used due to practical constraints, including unavailability and unawareness of certain media being at disposal.

In general, while defining the communication capabilities and providing examples for them, MST makes an assumption that media is appropriated properly — as we study actual, real use cases of communication media, we may not make such assumption, and therefore the need to distinguish the optimal potential and the realized, actual use of communication media becomes more apparent and indeed essential for the analysis.



**Figure 2.3.** Overview of Media Synchronicity Theory, adapted from [20]

The revised version rephrases some aspects of the original theory, introduce additional concepts — such as appropriation factors — to the theory, add more emphasis on communication processes, as well as update the concept of task and context to be more dynamic concept, evolving over time as people gain more experience on the task and of each other. Figure 2.3 shows the conceptual model of revised MST.

**Table 2.3.** Immediacy of feedback (1999) [22] vs. transmission velocity (2008) [20]

1999	2008
Immediacy of feedback is the extent to which a medium enables users to give <i>rapid feedback on the communications they receive</i> .... It is the ability of the medium to <i>support rapid bidirectional communication</i> .	Transmission velocity, derived from Shannon and Weaver’s capacity concept, is the speed at which a medium can deliver a message to intended recipients. While not expressly identified in prior theories of media, <i>transmission velocity is generally alluded to in terms of immediate or rapid</i> ... Media that are high in transmission velocity allow messages to reach the recipients as soon as they are sent. Therefore, messages spend less time in transmission. <i>Faster transmission velocity also allows a message to be responded to faster, meaning that the communication can approach continuous exchange with improved coordination and quicker feedback between individuals, resembling conversation</i>

The revision of 2008 renames the "immediacy of feedback" into "transmission velocity" (see Table 2.3 for exact definitions): "Immediacy of feedback is considered a capability of media (following the arguments in the initial version of MST), which we now consider as a socially experienced outcome resulting from use, not a capability of the media itself." [20]. Such change is mostly semantic: while high transmission velocity may not in some cases provide the sense of immediate feedback — e.g. if other party is busy, or refuses to answer — the communication medium still enables the potential for such immediate feedback. As such, for the scope of this thesis, terms immediate feedback and rapid transmission *can* be used interchangeably: for our analysis, we aim to be careful in keeping communication tool potential for immediate feedback and fluent communication speed and actualized communication speed separate, in cases when the two do not match.

**Table 2.4.** Parallelism (1999) [22] vs. parallelism (2008) [20]

1999	2008
This refers to the number of simultaneous conversations that can exist effectively – the "width" of the medium	Parallelism is the extent to which signals from multiple senders can be transmitted over the medium simultaneously.

The definition of parallelism has not changed considerably between the original and revised version (see Table 2.4). The 2008 revision does assume multiple senders, but in practice, such constraint might be irrelevant, as — at least for some media — multiple conversations may be active at the same time, and thus multiple conversations may occur between same participants. By reading and understanding the change strictly, 2008 revision would not count e.g. multiple discussion topics to be an example of high parallelism, unless each discussion topic has a different set of participants. Again, such distinction may or may not be relevant in actual communication media use, and is in any case largely semantic in nature, with limited to no applicability in analysis of communication media choice or use.

**Table 2.5.** Symbol variety (1999) [22] vs. symbol sets (2008) [20]

1999	2008
Symbol variety is the number of ways in which information can be communicated – the “height” of the medium – and subsumes Daft and Lengel’s multiplicity of cues and language variety	Symbol sets, derived from Shannon and Weaver’s types of symbols, are the number of ways in which a medium allows information to be encoded for communication, which we depict as the height of the medium in Figure 2, and subsumes Daft and Lengel’s (1986) multiplicity of cues and language variety

As with parallelism, the definition of symbol variety has not significantly changed between the original and revised MST (see Table 2.5). The renaming of symbol variety into symbol sets aims to address the issue between potential and actual communication media use, similar to revising the immediacy of feedback into transmission velocity: if a communication medium supports higher number of symbols, it does not immediately mean that all these symbols are actually used. However, in comparison to transmission velocity, it can be more difficult to consciously limit the use of symbol set, since for instance, in video conferencing — where transmission velocity can be altered by simply delaying the answer — it requires additional effort to limit one’s facial expressions.

**Table 2.6.** Rehearsability (1999) [22] vs. rehearsability (2008) [20]

1999	2008
Rehearsability is the extent to which the media enables the sender to rehearse or fine tune the message before sending	Rehearsability is the extent to which the media enables the sender to rehearse or fine tune a message during encoding, before sending

The definition of rehearsability (see Table 2.6) is essentially the same on both the original and the revised MST.



**Table 2.7.** Reprocessability (1999) [22] vs. reprocessability (2008) [20]

1999	2008
Reprocessability is the extent to which a message can be reexamined or processed again within the context of the communication event	Reprocessability is the extent to which the medium enables a message to be reexamined or processed again, during decoding, either within the context of the communication event or after the event has passed

The definition of reprocessability (see Table 2.7) has been changed to incorporate the reprocessability of messages even outside the context of original message, after the communication event has passed. For our analysis, as our focus was to study software projects, each message did implicitly have a context — at least, when understanding the context broadly, on the top level absolute majority of the communication within a project are grounded to that project specifically — even after the communication event had passed. As such, for the purpose of the analysis in this thesis, we do not believe any significant changes in interpreting and analysing the data, regardless of which version of reprocessability would be used, as most of the analysis is related to communication within the lifetime of a single project. In some cases, we do discuss about communication spanning multiple projects, such as lessons learned documents, but to some extent, such documents would still be interpret in a given context, and essentially should contain their own context as well.

## 2.7 Communication Media

There are many communication media available. This section aims at summarizing the most commonly used communication media in GSD projects and describe their features and capabilities for the scope of this thesis. Based on previous research, this thesis presents communication media used in GSD projects with following 7 main categories: Electronic mail, audio conferencing, telephone, video conferencing, instant messaging, desktop sharing, issue tracking systems and document repositories.

Electronic mail, or email, is a communication medium used to send primarily text-based messages from one sender to one or more recipients. Email does support sending any document as an attachment to the message, but this capability is often limited due to security policies or maximum message size in email systems. Email can be considered as de

facto standard for inter-organizational communication, as practically all knowledge workers have access to email systems. Email as a medium has primarily three main features for the scope of this thesis. Firstly, email is an asynchronous medium, meaning there is often a significant technical delay between sending the message and receiving it: sender cannot expect the message to arrive immediately, as sometimes — especially in intra-organizational communication — email delivery can take minutes. Secondly, email supports both one-to-one as well as one-to-many communication modes, both in terms of sending message specifically to multiple individual recipients as well as using a mailing list — a preset group of participants to whom the emails sent to mailing list are delivered automatically. Lastly, as mentioned before, email is primarily text-based medium, with sometimes limited ability to have other documents attached to the message.

Audio conferencing and telephones share the same underlying media capabilities, both being synchronous, audio-based communication media. However, the distinction between them arises from both the technology as well as differing use case for audio conferencing and telephone calls. Telephone calls — whether using plain old telephone system (POTS) or voice-over-IP (VoIP) — are understood for the scope of this thesis to be direct audio communication between two individuals, often initiated from their personal or individually assigned devices (telephones), while audio conferencing is often initiated either via computer-based communication tools or via fixed devices set up in meeting rooms. The use case difference between the two can be seen as telephone calls are more often than not ad hoc, unplanned calls while audio conferencing is in almost all cases preorganized and booked in advance, often on regular times (for instance, weekly meeting occurring on a specific weekday and hour). Video conferencing is very similar to audio conferencing medium, in most cases adding real-time video link between the participants.

Instant messaging (IM) is a synchronous communication medium. While many current IM tools support audio and video communications as well as desktop sharing, for the purpose of this thesis, IM is considered to be the text-based synchronous communication medium of such tools. Similar to email, IM supports both one-to-one communication mode as well as group messaging. The main differences between IM and email as a medium lie in the immediacy of feedback they provide — IM being synchronous and email asynchronous — as well as perceived formality of the medium, IM

being often considered as a less formal medium than email.

Desktop sharing is a tool, which provides all participants with a view of a presenter's desktop. This functionality is often provided in tools for collaboration over network, such as instant messengers and web conferencing software. Desktop sharing is commonly used in meetings, e.g. teleconferences, to provide all participants — not just those co-located with the presenter — with the presentation material, most commonly slides, synchronized with the actual presentation.

Issue trackers provide a way for structured asynchronous communication and collaboration in distributed software projects. The structure provided for collaboration is based on the issues — bugs, features or tasks — of the project. Issue trackers allow certain predefined states to be set for these issues, thus creating a workflow model for the management of them. In issue tracking systems, the issues are typically assigned to one or multiple team members, who may reassign the issue to other team members after they have performed a certain task related to the issue, or if they believe another team member should be responsible for further progress on that issue. In addition to status management and assignment of issues, issue trackers allow comments and discussion on specific issues. This functionality allows users of issue tracker to easily describe and share relevant information related to a particular issue, and thus provide a view on the history of the specific issue.

Document repositories are a group of communication tools which help to organize and share documents within and/or between organizations. Simplest form of document repository is simply a shared folder on a network server, while more advanced systems may include features such as fine-grained access control, version control and workflow capabilities. While document repositories may not be traditionally considered as a communication tool, they are included as one for the scope of this thesis as they do serve a role in communication and knowledge transfer in GSD projects, as well as they represent a form of extremely asynchronous communication.

## 3. Previous work

In this chapter, we review previous work on communication media choice specifically in the context of global software development.

### 3.1 Communication in GSD projects

Earlier research has shown that communication heavily depends on the distance between communicating parties [3]. Thus, communication is a challenge even in collocated software development settings, and it becomes even more problematic in global software development (GSD) projects, in which software is developed in physically separate locations [45, 44]. In GSD projects, challenges in communication have been found to significantly slow down the overall project progress [44]. In addition to physical distance, also other issues, such as cultural and time zone differences, organizational scale, and infrastructure availability contribute to the challenges in communication [46, 6].

A fairly large share of software developers' time is spent on communicating with other developers in the team. Perry, Staudenmayer and Votta report in their study developers spending on average 75 minutes each day in "unplanned interpersonal interaction" [79]. Earlier studies have reported the slower pace of GSD projects mainly to be caused by challenges and delays due to interaction over distance [37, 45, 46, 54].

The concept of distance is often split into three concepts: geographical distance, temporal distance and socio-cultural distance. For this thesis, we use fourth distance, organizational distance, which — while somewhat similar to geographical and socio-cultural distances — denotes the distance between different organizational units, and is manifested by both social constraints, such as different practices and conventions in different organizations, as well as technical and legal constraints, such as firewalls,

information disclosure constraints and conflicts-of-interest, to communication and collaboration.

### **3.1.1 Geographical distance**

By geographical distance we mean the actual physical distance between individuals. In earlier studies, it has been found that the frequency of communication between engineers would drop radically over a short distance ( $< 30$  m) and that the frequency would remain at the same low level over longer distances, whether the engineers were located 30 meters or miles apart [3].

Earlier research has attributed geographical separation as "the most significant factor affecting members' ability to develop shared knowledge" [25], and it was also found to be a source for loss of teamness due to lack of informal communication between team members in different sites [49]. Geographical distance does affect the project outcomes, even while some practitioners may feel that geographical distance may not be "a major impediment" to their projects [25]; the extent of decrease in performance of distributed teams may depend on the need for synchronicity on the given task — face-to-face communication seems to become more efficient option in comparison to mediated communication the more ambiguous and complex the task becomes [65].

### **3.1.2 Temporal distance**

Large geographical distance often implies also different time zones for different sites. This temporal distance — distance in time — further limits the possibilities for communication and collaboration between distributed team members [69]. The difference between time zones of different sites decreases the number of common working hours for both sites, thus limiting the opportunities for having shared, synchronous communications.

An earlier study has found time-zone difference to be the most frequently cited boundary affecting the project outcomes, either directly affecting the outcomes negatively, delaying the overall schedule of the project, or requiring more effort from project members [25]. Furthermore, temporal distance has been found to result in "extensive delay in responses" together with "feeling of being behind and missing out", as well as a potential source of communication overload, as the use of asynchronous communication tools increase the overhead for both creating and comprehending

messages [50].

Asynchronous communication makes it more difficult for remote team members to get familiar with each other, both in personal level but also professionally: team with relying only asynchronous communication is less likely to know each others expertise and specific knowledge [53]. On the other hand, successful and efficient use of asynchronous communication media may require team members being familiar with each other [19].

### **3.1.3 Socio-cultural distance**

Cultural differences manifest themselves as differences in tacit assumptions and expectations, as diverse working practices, and varying preferences for communication and collaboration methods [25]. Cultural and linguistic differences between team members lower the amount and frequency of communication between team members, as well as make the communication more formal between team members with different cultural backgrounds [25, 67], although machine translation may make linguistic barriers less of an issue [9]. Different cultures with different levels in cultural traits, such as power distance or uncertainty avoidance, may imply different focus on desired communication media properties and thus make certain aspects of communication media more relevant than others [1]. Organizational distance within project team may increase the need for especially synchronous communication, as team members from different organizational units seldom know each other beforehand [19].

### **3.1.4 Organizational distance**

By organizational distance, we mean phenomena resulting from working across organizational boundaries, whether they are caused by differing working practices, organizational culture, different roles and responsibilities, financial rivalry or technical impediments for collaboration. While many of these issues will be present when working with an external customer, involving multiple organizations to work with the actual software development is usually even more challenging, as organizational distance is introduced within the development itself, not only to distinct phases of development, such as requirements elicitation and delivery.

Organizational distance causes similar challenges to communication in distributed software projects as does cultural distance. Organizational

culture is often emergent in especially organizations with longer history: organizations both decide formally and converge informally into certain ways-of-working, conventions and practices, and also may exhibit and encourage certain set of values in their operations. Many distributed software projects may be built through relationships between either two organizationally separate entities, which may belong to the de jure part of the same company structure or be completely separate legal entities. In larger companies, it may not even be relevant whether the two organizations are part of the same company, as the organizational culture may still be different in different branches of the company, and as there might be intra-company rivalry and conflicting interests between the two organizations.

Beyond differences in organizational culture, explicit communication barriers may be in place between organizations. Such limitations are often in place due to legislation, contractual or financial reasons: e.g. subcontractors may not desire to reveal all details of their work to customer in order to be able to hold their positions in future contract negotiations. Organizational boundaries do affect how the overall project and its activities can be managed, requiring more formal monitoring and controlling methods [25]. Less friendly and less supportive environment may decrease the amount and frequency of communication between the members from different organizations [53]. To reduce the challenges caused by organizational distance, Holmstrom et al. propose near-shoring and limiting the number of sites per project [50]. However, in another study, while organizational boundaries were identified to have an effect on project outcomes, the actual impact was found both positive and negative [25].

### 3.2 Communication media use

To overcome the distance, and to augment the physical, face-to-face communication, GSD projects typically use a variety of communication media, such as the telephone, teleconferences, electronic mail and instant messaging [44, 95].

When physical co-location and face-to-face communication is not possible, video conferencing is often considered the closest alternative [95, 4, 31]. Regular video conferences between all team members has been found to increase trust between remote team members, and make everyone more motivated to collaborate with each other on daily basis [68, 40]. Some re-

search has found out that video conferencing might not be essential for maintaining team togetherness for established teams, as they might be able to convey and maintain social relationships through other communication media, most notably chat [24, 34].

Telephones and teleconferences have also been used to coordinate and collaborate over distance in globally distributed projects [37, 95]. In teleconferences, team members are often multitasking, i.e. attending to other activities or communication media during the meeting [56, 86]. One-to-one direct telephone calls were often used for urgent situations and problem solving [75].

Other synchronous media, such as instant messaging [39, 43, 64, 95] and voice-over-IP (VoIP) applications [85, 95] have become more and more commonplace in global organizations and especially in global software development projects. Especially in the context of GSD, instant messaging has been found to be quick and efficient way of communicating technical information and answering quick questions [52, 66, 4, 34, 24]. Near-synchronous and informal nature of IM has been found to be helpful in building trust and cohesion within the team [24, 71], as well as improving interactivity and communication processes [71]. In some cases, IM can even replace face-to-face communication in cases where physical co-location could make it possible, thus demonstrating the preference to use instant messaging instead of or in addition to meeting face-to-face, as it allows sharing of desktop and files between team members [56]. IM has also been found to be useful in transferring large volumes of information efficiently [4].

Earlier research has identified the central role of instant messaging as "glue" in communication mix of distributed projects [34, 35, 80]: "IM is often the medium where things happen if they do not have an established place anywhere else." [35]. IM was often used in parallel with other medium, e.g. while attending teleconferences [52, 82, 56]. In some cases, the IM conversation was used with team members who were attending in the same conference call, effectively as a back-channel or "invisible whispering" [82, 56].

Electronic mail has been used in global organizations for decades [91], and it still remains as one of the major communication media in globally distributed software teams [95, 28]. Earlier studies have found that despite occasional perceived overload from email communication, it is considered as efficient communication medium [71, 56], one study reporting



it to be "more efficient than formal meetings when learning about changes from the remote site" [56]. Email is often used to communicate technical information, and as a way to keep others aware of their current tasks [56].

In addition to mediated communication, face-to-face meetings still often have significant role in communication in GSD projects [74, 73, 95, 4, 86]. Co-located teams aside, a typical communication practice allowing face-to-face communication in GSD projects is visiting engineer [74, 4]. It has been found to be "a good communication method for rich information" [4], as well as to increase job satisfaction and motivation [86, 40]. Frequent visits are also found to be useful for transferring large amounts of information quickly and efficiently [73, 4]. Face-to-face communication has been found to be useful in training and mentoring junior developers [63]. However, it has been found out that unless a specific effort to build shared understanding during face-to-face meetings, co-located meetings can do more harm than good [7].

### 3.3 Communication media choice process

Earlier studies have provided support for MST. Findings indicate that high synchronicity was preferred for tasks requiring convergence, while conveyance of information was effective with tools of low synchronicity [81, 18]. It has also been found out that higher media synchronicity will lead to higher job satisfaction than lower media synchronicity [40]. Support of communication media for given communication need has been found to be related to higher task performance [60].

Earlier research shows support to MST, as it has been found that when performing tasks requiring convergence, the preferred media choice is often a medium with high levels of transmission velocity and a wide symbol set [32]. For brainstorming and idea generation tasks, rapid feedback has been found to be important, both to the number of new ideas generated, as well as to the quality of the ideas [36]. Furthermore, it has been found that media with low synchronicity, such as email, are not suitable nor preferred for tasks requiring either rapid feedback or convergence [27]. Especially for urgent tasks, rapid feedback seems to overrule other requirements, such as rehearsability or reprocessability, in GSD projects, probably due to willingness to resolve the issue at hand quickly [63].

Awareness of other team members is often regarded as an important factor in media choice [52, 66, 24]. Many IM tools provide up-to-date

awareness information about other parties, and thus allows initiator of the communication to choose communication tool accordingly [52, 66]. Furthermore, instant messaging provides a less obtrusive way to initiate a contact than a phone call, giving the recipient a chance to finish their tasks before replying [24].

Awareness of availability of others combined to parallelism of the communication medium affects the media choice, as higher parallelism allows participants to attend multiple communication events at the same time [66, 30, 52, 93]. In idea generation, it has been found that communicating over medium with higher parallelism may lead to higher number of ideas as well as ideas with higher quality, when compared to communications over media with lower parallelism [36].

The effect of symbol set in media choice is often related to the specific needs of the task; for instance, if detailed documentation is needed, a more structured and reprocessable medium is often preferred [24]. It has been found that the lack of additional cues, such as tone of voice or facial expressions, can hinder outcomes of negotiation tasks, thus making email communication less suitable for negotiations [76]. Similar effect has been noted in manager–subordinate communications, where lack of additional cues over face-to-face meeting can lead to suboptimal results [63].

Formality of the communication medium often affects how it is used, and for which purposes. Formal and structured channels are used to convey information, while more informal and freely formed channels may support team building and social integration [24, 31, 32]. In some cases, very rigid and formal communication media, such as document sharing systems or issue trackers, may become too complex and difficult to use, thus causing team members to resort to other communication media to perform their tasks [56].

Many studies have found that communication media with high reprocessability is often associated with the need to leave a trace, or to keep track of accountability [75, 63]. Within the team, this is often linked to lack of trust or confidence between team members or sites [63]. Redundancy of communication has also been shown to be beneficial in case not all team members are communicating with their native language [92]. Some cultural traits, especially uncertainty avoidance, makes it preferable to work with media that allow rehearsing and reprocessing the communication [1]. Reprocessability in communication medium has been found to make the communication medium useful also in transferring large vol-

umes of data efficiently within the team [31, 56, 42].

### 3.4 Effects of communication media choice

Recent research on media choice between audio-based and text-based media has confirmed the predictions of both media richness and media synchronicity theories to some extent[58]. Löber et al. [58] found out that text-based messaging scales better, i.e. that text-based communication sessions remain more efficient than audio-based media when the group size grows.

A case study by Scholl et al. [85] confirm the usefulness of text-based medium. The issue of language skills of communicative parties related to media choice has been discussed in previous work, suggesting consideration on participants' abilities to process information when using rich and high-volume communication [90, 62].

Previous research has identified that more successful teams in terms of both quality and productivity, seem to rely more on linchpin developers that become more active as the team's temporal distribution grows and serve as "bridges" between time zones"[13]. Such finding is in line with MST, as it was found that these bridge developers are able to use a wide array of both synchronous and asynchronous media [13].

There has been research not showing significant impact of media choice on the quality of task outcomes, but media choice still affecting the time it takes to complete the task, the overall satisfaction in communication and on individuals perception of their participation level [41].

Calefato et al. [10, 11] studied using computer mediated communication (CMC) on requirements engineering (RE) tasks. They studied 6 projects, randomly assigned to use either text-based communication tool or face-to-face for requirements elicitation and negotiation [10]. They observed that face-to-face communication might not be the most optimal medium for requirements engineering, as "support for structured discussion, proper documentation, and visibility of decisions made, as well as increased ability to discuss openly conflicting issues" made text-based communication more efficient in requirements engineering [11]. They noticed that perceived performance of communication medium differed depending on the RE activity: text-based communication medium was better task-fit for requirements elicitation, while face-to-face communication was better fit for requirements negotiation [10], as "the development of common ground, es-

essential to achieving shared understanding of requirements” is more difficult in requirements negotiations over text-based communication medium is more difficult than when eliciting requirements [11]

Earlier research has identified the weak understanding of remote teams’ work and the lack of shared context a major issue in globally distributed projects [6]. This becomes even more pronounced when remote team members have limited access to customers and their insights, as tacit knowledge and assumptions may become misunderstood or not communicated at all [6].

A study on team changing from face-to-face communication to email found out some support to the claim that there are negative effects, such as feelings of loneliness and isolation, when synchronicity of the communication medium is lower [28].

In any case, building shared understanding, mutual trust and teamness over mediated channels requires both time and effort from all participants [26, 7]. It is therefore recommended to allow extended time periods before assessing usability, suitability and efficiency of a communication medium for a specific context and team [26]. Previous research has shown that informal and socially oriented communication may help to reduce anxiety related to communication tool use, and therefore improve the performance and satisfaction in collaboration using computer mediated communication tools [29].

Study on communication media choice by managers has concluded that managers prefer to use rich media for ambiguous communication, and leaner media for unequivocal communication [17]. Overall team performance and communication performance has been reported to correlate positively when using telephone, and negatively, when using video conferencing [62], a result contradicting with media richness theory. Many media choice theories, including media richness theory, media synchronicity theory and social presence theory, as well as previous research often emphasize the performance of the communication medium, or the fitness between medium and task to be performed. Overlooking the effects of user satisfaction with the communication tool [48] can lead to inefficient communication and lower experienced communication performance [2].

Often, the choice of communication media seems to be based on convenience, as the medium is selected based on also other factors beyond the needs of the communication task [80], such as personal preferences, team and company policies and communication media availability [80, 27].

In a study consisting of undergraduate students, the differences between convergence and conveyance as communicative processes were identified in tasks related to decision-making [23]. While many tasks involve both conveying information and converging on shared meanings, it was found that a single communication medium is often unable to both convey information and converge knowledge [23]. However, prior work has also found that synchronous and asynchronous communication media augment each other, as synchronous media was used as a information rich communication channel, and asynchronous media as a semantically rich channel [81]. Earlier studies have showed the benefits to building mutual understanding, context awareness and technical knowledge by combining several communication media for communication needs of a distributed team [81, 18, 31].

Research by Mohan et al. [63] found out that media choice is often directed by specific media characteristics rather than aggregate media characteristics. As an example, they found out that if document trail was a desired feature of the communication media, email was chosen as the medium to be used, while tasks requiring fast turnaround, face-to-face meetings or telephones were preferred [63]. In cases when specific requirements were conflicting or contradicting, they found that teams chose to use multiple media [63]. Further research has also confirmed MST's proposition that the use of multiple media leads to stronger interpersonal relationships between participants and improve their communication and work performance [72, 71].

Earlier studies identify a number of factors beyond MST affecting media choice. Aspects such as media familiarity, availability of medium and "infrastructure capabilities" have been found to be significant drivers for media choice, yet not significantly recognized within MST framework [27, 60, 61].

## 4. Methodology

In this chapter, we present the research questions and the research methodology used in the study.

As software projects are by definition unique, and we had limited prior knowledge on the projects, the tools they had available for use, and how they were using the tools, we decided to conduct an explorative qualitative study on communication tool use in GSD projects. The study was composed of collecting data via semi-structured interviews in several software companies, and analysing the data by codifying the interview transcripts.

In addition to qualitative interview study, we measured the communication media use patterns in one case project.

### 4.1 Research Questions

We were interested in investigating the actual communication tool use and choice in industrial software projects. As communication is an essential part of collaboration in software projects, and as distributed software teams must mostly rely on mediated communication, the research problem becomes how to choose which communication media to use in a GSD project, and whether that decision really affects the outcomes of the project.

After assessing which communication tools and media could be and in fact are used in GSD projects, the use of those media can be studied. By looking at the context of GSD projects, the situations when a communication medium is used, the rationale of choosing a particular communication medium to meet a specific communication need, and matching these into the practitioners' experiences and observations on how successful their communication was, the potential and extent of individual and work context factors can be studied.

Another angle on communication media choice in distributed teamwork is to look whether the decisions on which tools to use in collaboration and communication does affect the outcomes of the project. Since software projects are generally fairly difficult to measure itself, the successfulness of communication can be assessed by studying on the other hand the communication satisfaction, efficiency and effectiveness perceived by individual team members and others closely working with teams, such as customers, and on the other hand the overall teamwork quality and job satisfaction, especially components that are rooted in communication between team members across sites.

As stated in the introduction of this thesis (see chapter 1.2), the research problem for this thesis is: *How is communication media chosen in globally distributed software projects?* We choose to investigate this research problem through following research questions:

RQ1 Which communication media are used in GSD projects?

RQ2 Which individual and organizational factors affect the choice of medium for communication in GSD projects?

RQ3 Does the choice of communication medium affect team members' satisfaction on communication?

RQ4 Can proper communication tool choice improve the perceived efficiency and effectiveness of communication in GSD teams?

## 4.2 Case Selection

We used purposeful sampling [77] for choosing the projects to be studied. Firstly, the three companies studied in this research were participating in our research project. These companies were purposefully selected for the research project, based on both company and researcher interest and convenience. All selected companies were engaged in GSD, interested in improving their capabilities in global software development, and able to provide several on-going GSD projects for the study. The projects for this study were selected in collaboration with the company managers and the researchers.

We asked the companies to provide us a set of distributed software projects with high level of collaboration between the sites in the project containing both successful and challenged projects. The distinction between successful and challenged projects was made by the company representatives, based on their own evaluation, and their assessment on project status was not disclosed to researchers. Secondly, the projects were selected based on convenience and interviewee accessibility for researchers, as personnel from all project sites were included in the interview study.

**Table 4.1.** The projects studied

	Company	Domain		On-site	Off-site	Team size	Interviews
A	1	Enterprise resource management		Finland	India	14 + 25	3 + 1
B	1	Information system		Finland	Lithuania	9 + 6	3 + 2
C	1	Information system		Finland	Lithuania	60 + 8	4 + 3
D	2	Communication system		Finland	Czech Republic	6 + 26	2 + 4
E	2	Legal system		Finland	Lithuania	11 + 6	8 + 4
F	2	Enterprise resource management		Finland	Czech Republic	17 + 19	5 + 4
G	2	Financing		Finland	Czech Republic	20 + 11	5 + 1
H	2	Enterprise resource management		Germany	Czech Republic	25 + 43	0 + 4
I	2	Enterprise resource management		Norway	Czech Republic (+ Sweden, Finland)	35 + 17	7 + 4 + 0
J	3	Engineering software		Finland	Malaysia	45 + 7	5 + 1
K	3	Engineering software		Finland	Romania	45 + 5	5 + 5
L	3	Engineering software		Finland	Russia	45 + 5	5 + 4

Table 4.1 shows an overview of the selected projects. The number of people directly involved in these projects was between 15 and 68 per project. Altogether we interviewed a total of 79 people from these twelve software projects. All twelve projects were globally distributed, i.e. the work conducted was performed on multiple sites located in different countries. The main site (“on-site”) was typically responsible of product ownership and project coordination, while the other site (“off-site”) of the project was focusing on the project implementation issues. Some of the projects had stakeholders in other sites as well, but these stakeholders were mostly supporting the projects as specialists, and usually not directly involved in daily project work.

Each project was using English as their working language, even though



practically no team member spoke English as their native language. In project H, some communication between on-site and off-site was conducted in German, and in project I some interaction between Swedish and Norwegian team members was conducted in their respective native languages.

Ten projects (A–J) were intra-organizational — all sites belonged to the same consolidated company. The reason for utilizing global resourcing in these projects was both cost benefits and unavailability of personnel with needed skills at on-site location.

Two projects (K and L) were inter-organizational, i.e. off-site team was part of an external subcontractor company. In these projects, the aim of distribution was to focus on core competencies of the on-site company, to access competent work force for the projects, and to build sustainable ecosystem around the core product. The on-site personnel in projects J–L are the same personnel, working mostly for the core part of the product, while off-site teams were working on separate add-on functionality on top of the core product. Thus, the work conducted by off-site teams in project J–L was distinct, and those teams had very little to no contact with each other, as they were working on unrelated add-ons to the product.

4.3 Data collection

Table 4.2. Data collection and analysis time line

Activity	When
Study design	Jan 2007 - Apr 2007
Interviews	Apr 2007 - Jul 2008, Apr 2009
First Data Analysis Pass	Aug 2007 - Mar 2008
Detailed Data Analysis Pass	Nov 2007 - Feb 2009, Nov 2011 - Mar 2011
Face-to-face & Digital Communication Data Collection	Mar 2009 - May 2009
Communication Data Analysis	May 2009 - Aug 2010

We collected the data using semi-structured, open-ended interviews. Altogether this study includes a total of 79 interviews from 12 software projects. We purposefully selected a subset of team members to interview in collaboration with project managers of projects, to include both on-site and off-site personnel to be interviewed. The interviewees represented different roles, ranging from high-level business managers to software developers. The overall time line for data collection and analysis is shown in Table 4.2.

**Table 4.3.** Interview Themes

Theme	Topics Covered
1. Interviewee Background	Informant background, roles and tasks in current project, work experience
2. Collaboration Background	Length and type of collaboration, reasons for collaboration
3. Project Background	Purpose of collaboration, parties, roles and teams involved, current project schedule
4. Beginning of the project	Project ramp-up, work division, requirement specification, training
5. Process model	Process model in use, iterations, delivery cycle, problems / benefits in current model
6. Data management	Version management, change management
7. Monitoring	Progress monitoring, reporting, transparency
8. Communication	Roles, meetings, media use, communication efficiency
9. Trust & feedback	Trust between sites, mutual support, familiarity with distant team members, style of communication
10. Distance	Cultural differences, geographical distance, power distance
11. End of project	Lessons learned from previous projects, debriefing current project
12. Problems / successes	"Mention the three most important problems & successful practices"

The question set contained open-ended questions [78] on 12 themes (see Table 4.3) related to software engineering and GSD. We asked our interviewees to tell in their own words about their project context, processes and practices in use in the project, and group relations within the project. The length of a typical interview was two hours, with one interviewee and two interviewers present. One of the interviewers was mainly asking questions while another interviewer was taking interview notes. Interview notes were used to further identify the specific interest areas on each project, to share information between the researchers and to guide the further interviews. We continued to interview people from a single project until we had covered all the different roles in that project, and until we believed we had reached saturation in terms of new data and viewpoints with regards to that particular project. Interviews were conducted in Finnish when applicable, and in English in the case the interviewee was not native Finnish speaker. All interviews were recorded and later transcribed by an external party.

For project I, we also collected face-to-face interactions, as well as email and instant messenger communication logs. Face-to-face interactions were collected using Sociometric Badges, developed at MIT Media Lab [94]. Email and IM data was collected by asking participants to archive and keep all their email and IM communication related to the project, and then to export this data at the end of the study. The purpose for collecting the actual communication data was to in part validate and verify the previous findings, especially related to communication pattern differences between face-to-face, email and IM.

#### 4.4 Data analysis

We analysed the interview data in two passes, first to analyse and identify the different aspects or themes of GSD, and secondly to identify phenomena associated with communication practices and tools. All research articles included in this thesis follow the same basic structure for data analysis.

The first pass of qualitative analysis for the interview data was thematic coding [57] using Atlas.TI software, codifying the data for different themes of global software development. Thematic coding of the data was done in collaboration with other researchers in the research project. Although we did not rigorously assess the inter-rater reliability in our thematic coding for the whole data set, author and another researcher did codify the same two interview transcripts, and found the agreement on codification high enough <sup>1</sup> for further analysis.

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<sup>1</sup>The agreement on codification was 82 percent

**Table 4.4.** Final Code Set from First Pass of Communication Media and Practices Analysis

Category	Sub-code
Task type	Generating ideas and plans
	Choosing correct answers (intellective tasks)
	Choosing preferred answers (judgment tasks)
	Negotiating conflicts
	Leadership, management and administration
Communication media	Text-based
	Audio-based
	Video-based
	Face-to-face
Experiences	Communication performance
	Communication satisfaction
Media choice factors	Personal preference
	Initiator availability
	Recipient availability
	Media availability
	Participant role
	Message urgency

Secondly, all quotations related to communication practices and tool use were codified with more detail. For this more detailed codification, several different approaches were used in various stages of the research. First stage of the analysis was based on applied grounded theory, and thus made without any predefined codes. We allowed the salient phenomena from the interview transcripts to guide the codification process, adding new codes and splitting the existing ones throughout the codification process. The final code set for this first pass of more detailed codification on communication practices and media choice is shown in Table 4.4. This analysis was used in [PIV] and [PI] and formed a basis for analysis for [PII], [PV] and [PIII]. The purpose for this approach was both to explore the collected dataset as well as to guide further, more detailed analysis.

**Table 4.5.** Codeset Used for MST Specific Analysis

Category	Sub-code
Communicative process	Convergence
	Conveyance
Communication media	Email
	Teleconferencing
	Telephone
	Videoconferencing
	Instant Messaging
	Desktop Sharing
	Issue Tracking
	Document Repository
	Version Control System
	Face-to-face
Media property	Feedback
	Parallelism
	Symbol Variety
	Rehearsability
	Reprocessability

Second stage of the analysis was performed with code set derived from Media Synchronicity Theory (see Table 4.5), and was used to find evidence of media choice activities supporting or opposing the MST. This MST specific detailed codification was coded on top of previous codification, and was used in [PII], [PV] and [PIII].

Thirdly, face-to-face, email and instant messaging data was analysed using social network analysis. We used sociometric badges developed at the Massachusetts Institute of Technology Media lab [70], to automatically collect data on face-to-face communication between colocated members of the teams. A sociometric badge is a device containing a microphone, an infrared sensor, and a radio receiver [70]. Email and instant messaging data was collected by collecting logs from respective communication tools. In total, we collected data for six weeks.

The software used to perform social network analysis and digital communication data collection and analysis was developed by the author in Python programming language<sup>2</sup>, using NetworkX<sup>3</sup> social network analysis library. We analysed the connections between different team mem-

<sup>2</sup><http://www.python.org/>

<sup>3</sup><http://www.networkx.org/>

bers within the same site and across different sites, and compared the number of interactions across these three communication media. We also analysed the number of messages exchanged between individuals and different sites. This quantitative analysis of communication patterns and volumes was used in [PVI].

#### **4.5 Verification and Validation**

In order to further verify and validate the analysis and interpretation of the data, we organized feedback sessions for project members from projects studied as well as workshops open to general public. The purpose of these sessions was to present our results and preliminary findings, as well as keep our informants, their colleagues and company management engaged in our research. From research perspective, we used these sessions to reflect, further discuss and validate our findings, and to gain additional insight to the topics studied. While we did not rigorously document these sessions and the discussion in these sessions — partly due to the sensitive nature of especially the feedback sessions internal to project teams — we are confident that since no major concerns against our interpretations and results were raised, our analysis and results are agreeable and fairly accurate in terms of internal validity.



## 5. Results and Discussion

In this section, the results of the research are summarized. This section is organized based on the research questions introduced in section 1.2. In each section, the central observations and results are presented, with more detailed results and discussion available in the respective research articles.

### 5.1 RQ1: Which communication media is used in GSD projects?

The first goal of this thesis was to find out which communication media was used in GSD projects, and for which purposes.

Based on our findings, the three most commonly used communication tools in the projects studied were email, audio conferencing, and instant messaging [PII]. In addition to these three main communication tools, projects did use a number of auxillary tools, which supported task-specific needs, such as desktop sharing, issue tracking systems, version control systems and document repositories [PII]. Table 5.1 summarizes which communication tools were used in GSD projects studied [PII]. In Table 5.1, xx denotes tool being used by most team members, while x indicates tool was used by only a subset of team members.



**Table 5.1.** Communication tool use in projects (from [PII])

	Email	Audio confer- encing	Telephone	Video confer- encing	Instant messag- ing	Desktop sharing	Issue track- ing	Document reposi- tory
A	xx	xx	-	xx	xx	x	xx	xx
B	xx	xx	xx	x	xx	x	xx	xx
C	xx	xx	xx	-	xx	xx	xx	xx
D	xx	xx	xx	-	xx	x	-	-
E	xx	xx	xx	xx	xx	-	xx	xx
F	xx	xx	x	-	xx	-	-	xx
G	xx	xx	x	-	x	xx	-	-
H	xx	xx	x	xx	xx	xx	xx	xx
I	xx	xx	x	xx	xx	-	xx	xx
J	xx	xx	x	-	xx	-	xx	xx
K	xx	xx	-	-	-	-	xx	-
L	xx	xx	-	-	-	-	xx	-

xx Tool used by most if not all project team members

x Tool was used only by minor subset of project team

- Tool was not used in the project

All projects we studied had multiple communication tools at their disposal and in actual day-to-day use. Each project seemed to be relatively autonomous in selecting which communication tools they choose to use, and how those tools are used to support their collaboration and communication needs. Based on our interviews, none of the projects had an explicit communication plan or guidelines on which tools should be used in which cases. At the same time, companies did provide a preselected set of communication tools, and in most cases, project staff was allowed to use only those communication tools approved and endorsed by the company. Thus the media choice was done mostly ad-hoc, on an on-demand basis on both the project and the individual level. In some of the projects studied, there were clear differences in preferences for communication tool choice between individuals, which had lead to conflicts or miscommunication in the past. [PII]

In software projects, the need for communication is versatile. Different phases of software development, such as requirements elicitation, architectural design, implementation and quality assurance, have different needs for communication and communicative processes, and thus emphasize different media capability in media used. While many implementation tasks mostly require one-to-one communication, i.e. finding the correct or preferable answer to a problem, there are several occasions

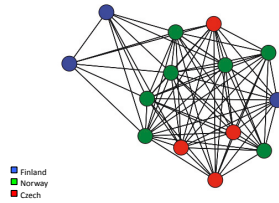
where one-to-many or many-to-many communication is needed, such as project status reporting or architectural design. One-to-many communication was commonly needed to share information about the project, while many-to-many communication was often used to find preferred solutions and to solve problems. As there are different communication modes for these different communication needs, and available communication tools differ in their support for different modes, the communication mode supported by the communication media chosen is an important factor for media choice in software projects. [PI]

The following subchapters present how each communication medium was used in the projects studied as well as our observations.

### **5.1.1 Email**

In one of the projects studied, project I, the main use for email was to communicate team-wide issues [PII] [PVI]. Project team wide distribution was used to communicate administrative and managerial information, such as project announcements, status reports and meeting minutes [PI]. In this project we collected quantitative email data, such use of email was reflected both in the social network graph based on email messaging — shows all team members from all sites equally immersed in the graph — as well as in the average number of recipients in each message — indicating that a significant number of email messages sent did include all project team members as recipients [PVI]. Using broad distribution lists for emails in projects seems to lead into increased awareness of project status and of the currently acute issues the project is facing [PI].

Some of the other projects studied did also use project wide mailing lists as a forum for generating new ideas and for problem solving activities. However, in those projects, some interviewees reported the use of mailing lists for idea generation and problem solving to be often difficult, due to both large volume of messages as well as the lack of proper structure for discourse. [PI]

**Figure 5.1.** Social network based on email

Emails were used in communication spanning multiple sites in distributed teams. When we collected email communication patterns in Project I, we were able to see the network was relatively equally dispersed based on the site each project team member was located in (see Figure 5.1). Furthermore, when we took into consideration not only who communicated with whom, but also number of messages sent, we saw that majority of messages did span site boundaries. However, we did see the main site using email even more in communicating internally than to communicate with other sites. We believe this could be affected by both the specific managerial roles assigned to team members on that site (project manager, scrum master) as well as the frequency of telecommuting at that site. [PVI]

### 5.1.2 Audio and video conferencing

Audio conferencing — e.g. group telephone calls, or multiparty voice-over-IP sessions — was the second most commonly used communication tool in the projects studied: all projects used audio conferencing at least on a weekly basis. Audio conferencing was a readily available communication medium for all projects studied. The use of audio conferencing was straightforward, as all project members were familiar with the technical and social conventions of audio conferencing. [PII]

In all projects, audio conferencing was mainly used for weekly team meetings, in which all team members reported their progress in, current challenges in their work and new ideas for the project [PI] [PII]. As such, audio conferences were mainly used for coordinating work within the team, providing team awareness about what other team members and other stakeholders were doing at the moment, resolving technical and social conflicts, as well as collecting new ideas and improvements for the product, project and ways of working in general [PII]. In many cases, the teleconferences were augmented by documents (e.g. task list, project plan

or presentation slides), delivered typically via email and in some cases via screen sharing software [PI].

Audio conferencing was used for both one-to-many and many-to-many communication. Typical one-to-many use case included project manager or other person in managerial role announcing important issues for the whole project team. Many-to-many communication mode was used to resolve any conflicts within the project and project team, and to innovate new solutions for the challenges project was facing. In many cases, meetings started with one-to-many mode with project news and announcements and then turned into many-to-many discussion about project status and problem solving. [PI]

In one of the projects studied, the team regularly used a part of the team's weekly audio conference meeting for non-work related social topics. In practice, each team member was invited to describe their latest experiences in their personal life lately, to share with others what they had done during the previous week or what plans they had for the week ahead. This was found especially useful in building understanding on the different cultures present in the team, and to provide additional information about the particular working context and environment on the remote site. [PII]

In some projects, audio conferencing was used for smaller groups — or sub-teams — to discuss about their activities across sites: purpose and communication practices in those cases were similar to team-wide meetings, but the formality of meetings was often more relaxed, as the number of people involved was smaller and often were more familiar with each other [PII]. One-to-one telephone calls were not that frequent, but used in many projects for exceptional and urgent situations, such as solving a critical problem [PI].

The frequency and length of team meetings over audio conferencing varied a lot between different projects: some projects had daily meetings which lasted only 15 minutes [PVI] while others had weekly meetings lasting several hours [PIII]. Especially when working across time zones, the time difference between sites does constrain the scheduling of the meeting, and also limits the maximum length for the meeting [PIII].

Some projects did use video conferencing instead of or in addition to audio conferencing. Video conferencing did extend the capabilities of audio conferencing by adding even more symbol variety to the medium. In video conference, in addition to tone of voice, the visual link provides partici-

pants more cues on the reception of their message in forms of facial gestures. The addition of gestures to audio conferencing helps participants to anticipate the communication of others, and thus may help to keep the meetings more disciplined. Compared to audio conferencing, parallelism can be even lower, as visual contact enforces the social norms to focus on the meeting at hand, and not to multitask on other activities during the meeting. [PII]

### 5.1.3 Instant Messaging

Instant Messaging (IM) was also commonly used in the projects studied [PII]. IM was mostly used for relatively simple discussions, such as asking for specific technical details or coordinating work across sites [PIV]. The main benefit from IM for these purposes came from its ability to convey messages rapidly [PIV] [PII] [PV]. This finding is observed by earlier research as well [52, 66, 83].

Team members were satisfied on IM to communicate technical issues, as long as there weren't any major issues and people communicating were already at least somewhat familiar with each other [PIV], [PII], [PIII]. While discussing more complex issues over IM was possible, in many cases team members preferred to use other media, usually teleconferencing and face-to-face, first, to build initial understanding of the problem at hand, and once the basic level of understanding was in place, IM would be used to further coordinate the issue and maintain understanding on the subject [PV]. This finding is also in line with previous research [93, 52, 66], meaning IM is not especially well suited for converging understanding as it is for conveying information [10, 11, 51], an observation also predicted by MST [22].

IM tools used in projects also provided presence awareness, a feature that allowed other people know whether someone was available for communication. In addition to establish basic understanding about presence of other people, in some projects the status information was used to convey information about their actual availability and willingness to communicate. The presence status message was used to guide others in which communication tools should be used for the communication. When starting a discussion over IM, people often wanted to make sure the visible status in the IM tool was in fact correct, and that people were actually willing and able to take part in the conversation. In some projects, the presence status information from the instant messaging tool was used to interpret

what other team members were working on, by publishing information about their current tasks in their IM status messages. [PIV]

Earlier research also suggest presence awareness is beneficial for distributed teams: the awareness of presence of other users may enable more communication within the organization [66], it may especially increase the amount of informal communication between colleagues in different sites [43], and makes the communication less intrusive for recipients [43].

As IM is a text-based medium, it provides relatively low symbol variety: facial expressions and gestures as well as tone of voice are left out, which reduces the communicative parties' ability to verify the context of the message [PII]. To overcome this, frequent IM users often add emoticons (smileys) to their messages, to guide the interpretation of tone of voice [PII].

Parallelism, rehearsability and reprocessability are at medium-high levels: as there is no expectation of immediate response, one can conduct other activities or revisit the communication between individual messages [PII]. Previous research has also reported multitasking to be common while engaged in IM communications [52, 66]. In addition to multitasking between different activities, it has also been reported, that users can be engaged in several instant messaging conversations simultaneously [30, 52, 66, 93].

Temporal difference caused however some limitations to the synchronous communication. Especially in projects, where sites had longer temporal distance, communication over IM was possible only during certain hours of the day [PIII]. Often, if an important decision is made during IM conversation, email was used to notify all other affected parties about the decision [PIV]. Sending out an email message about the decision also acts as a way of storing and documenting the decision [PIV]. The importance of persistence of IM discussion logs has been noted in previous research, too [5, 33].

#### **5.1.4 Auxillary communication media**

In addition to three main communication tools, email, teleconferencing and IM, the projects studied had a number of other communication and collaboration tools available. Such tools include issue trackers, version control systems, document repositories and desktop sharing tools. These tools could be described as add-ons to the main three tools mentioned ear-

lier, as they were rarely used independently, but rather they augmented the three main communication tools. [PII]

Issue trackers provide a central repository for tasks, bugs and other issues related to the software project or product. Issue trackers can be integrated into other communication media. Typically, issue trackers are connected to email, so that email notifications can be sent whenever there are new issues assigned to a team member, or if the status of a followed issue has changed. Some projects have integrated their issue management and IM systems, allowing team members to instantly be informed of any issues assigned to them. While such integration with other communication tools was generally seen as a positive thing, it sometimes caused confusion about what tools should be used for further communication on the issue and how discussions conducted outside the issue management system should be documented. [PII]

Desktop sharing was commonly used to augment teleconferences by sharing presentation slides, information systems such as issue trackers, or the software product at hand to remote participants. Desktop sharing was used for demonstration purposes in one of the projects studied. The desktop sharing technology enabled team members to demonstrate the functionality of the software to customer remotely, without the need to meet face-to-face or to train on-site personnel on the demonstrated features. Desktop sharing was also used for remote training of new team members, as well as for problem solving and when working together with a remote pair. [PII]

### 5.1.5 Discussion

While projects studied had a diverse set of computer-mediated communication media at their disposal, nearly all of them used two or three of following: email, audio conferencing and instant messaging. In addition to these main media, each project had a number of auxiliary tools they used to communicate, often specific to their project scope or organizational needs [PII].

Earlier research has also reported the use of multiple communication tools in GSD projects, noting that email and teleconferencing are most often used in GSD projects [44, 95, 28].

The actual use of these tools was heavily varying from one project to another: some project teams used several tools to communicate, while other teams were relying on only two or three tools on daily basis. The

variance in tool usage was also apparent within a project team: sometimes the use of a certain tool was limited only to a specific subset of team members. Especially in project teams with higher role specialization between team members, it is natural that some tools may be dedicated for specific tasks or phases of software development. However, such division was sometimes also due to technical or business limitations (e.g. another organizational unit did not have access to the tool) or based on personal preference or reluctance to adopt new communication tools. Earlier research has reported similar findings [80, 27, 63].

Email was used as a generic communication media, catering almost all needs in projects. It was often used as a fall-back medium, when communication over other medium was not possible. In addition to one-to-one email communication, one major use for email was to communicate project-wide issues as a distribution list to all project team members and other stakeholders. Our findings on how email was used in GSD projects seem to be aligned with previous research [71, 56].

IM was used to communicate simple questions and clarifications, as well as technical decisions and solutions for software defects or features. Some projects more actively exploited the multitude of features provided by IM, and e.g. using it for communicating presence and availability to communicate. IM presence status was sometimes also used to provide additional awareness of whereabouts, availability and current tasks of individual team members. Earlier research has reported similar use of IM to ask quick questions and to clarify availability [24, 71]. Previous work has also identified the role of IM as a "glue" between all other communication media" [35].

Audio and video conferencing was commonly used for regular team meetings, but occasionally also for smaller meetings. It was also used to communicate with customers and other stakeholders. In many cases, desktop sharing and IM was used to augment the main conferencing medium. The contents of audio and video conferencing meetings was often related to coordinating work between team members, solving problems and coming up with new ideas for the project. One-to-one telephone calls were mostly restricted to exceptional, urgent problem solving situations, whether they be organizational or technical in nature. Previous studies have also found the use of IM and teleconferencing together [82, 56]. Earlier research has also had similar findings with regards to telephone calls being used mostly to exceptional situations [75].



Other communication tools, such as issue trackers, version control systems and document repositories had more task-specific use, and they were often used in conjunction with other communication tools, such as email and instant messaging. Earlier research has shown the benefits of structured, formal communication media in transferring large amounts of information quickly [31, 56, 42]. On the other hand, too complex and rigid communication tools may not be considered useful in practice, and other communication media will be used instead [56].

When we reflect the stated use of communication tools to MST, we notice that in most cases the communication media choice seems to fit MST suggestions. For instance, using email to communicate team-wide, non-urgent issues is supported by the fact that email is asynchronous medium that allows great deal of rehearsability and reprocessability — thus allowing communicative parties both to send and receive messages at their own pace. Ability to review potentially complex, non-urgent messages at convenient time allows people to moderate their own focus and concentration to a task at a hand, and helps them understand and process information at a level that is required for the message.

On the other hand, problem solving often requires immediate attention, and thus using a synchronous communication media for those tasks is more appropriate based on MST. Problem solving often requires input from multiple stakeholders, and also immediate feedback and discussion back and forth is useful when dealing with uncertain, ambiguous concepts. In some projects, team meetings also had a function as a forum for building mutual understanding and personal relationships between team members — especially from remote sites — and the additional cues provided by audio-based communication over text-based medium does help to reach this goal.

Earlier research has also found evidence supporting MST in finding media supporting high synchronicity were preferred for tasks requiring convergence, while media of low synchronicity were preferred for tasks requiring conveyance of information [81, 18], and as better fit between communication needs and tool support seem to increase work performance [60] as well as job satisfaction [40].

## 5.2 RQ2: Which individual and organizational factors affect the choice of medium for communication in GSD projects?

Second research goal was to find out which factors affect media choice in GSD projects. We found several clusters of reasons to choose one medium over another: language skills, project role and tasks, culture, project and organizational set-up, availability and cost, and technical constraints. In following sections, we will discuss each of these reasons separately, and finally provide a summary of all of the factors we observed affecting media choice in GSD projects.

### 5.2.1 Language

In GSD projects, English is typically used as the working language, especially when working across sites. As people are working in different countries, this leads to a mix of multiple dialects of English language to be used in the project. In the case projects we studied, English was not usually the native language for any of the team members on either site. In many cases team members from different sites had challenges understanding each other because of the language barrier due to different dialects and non-native speakers. Often, this led to preference and need to use text-based communication medium to clarify and validate what people from other sites were communicating. [PI] [PII]

Some team members preferred to text-based media especially in cross-site communication situations, as it "neutralized" the dialect, and made the language more comprehensible. They felt they were more competent in using their English in written form rather than speaking the language. We found out there sometimes team members felt they were not able to express themselves in foreign language well enough, and thus did not ask questions or clarifications on ambiguous issues in meetings. This extended also to a higher barrier to initiate audio-based communication in general, even leading to a total refrainment from the communication with remote site altogether. We found out that for people too afraid to speak foreign language, text-based medium, even if it was near-synchronous such as instant messaging, gave them some time to think and find the correct words in discussion, and thus allowed them to communicate in real-time with people from remote sites. [PI]

Medium with high rehearsability allows communicative parties to spend more time preparing their message. On the sending side, this extra time

will enable people with lower self-esteem or skills with foreign languages to participate in communication more actively and openly, and thus making the communication more enjoyable for them: The effects of rehearsable medium were noted on the receiving side as well. As senders were able to refine their messages, and make sure what they wrote made sense and was in fact understandable, teams were able to overcome language barriers and differences in accents of spoken language. [PV]

### **5.2.2 Team member role and tasks in project**

The working role of a person seemed to affect the media choice for communication. In projects studied, technical personnel – e.g. developers, testers and architects – preferred text-based communication media over audio-based communication media. We found out that even in cases where technical personnel had the same communication media available as other project staff, they were usually preferring to use text-based tools when they themselves initiate communication. The preference for text-based tools may be related to several issues specific to their work items and working environment: they felt it was easier and more precise to express technical issues such as source code lines or error messages in written form. [PI]

In software projects, technical personnel is most involved in the actual technical artifacts of the project. These technical artifacts include software source code, configuration files, infrastructure files (e.g. build scripts) and test cases. In many cases, technical artifacts in software projects are both complex and usually difficult to express verbally, as they are typically composed of abbreviations, keywords and special characters not part of natural languages. In addition, such technical artifacts have a high requirement for preciseness, e.g. code lines must be replicated in exactly correct form in order to be valid. Given these constraints, the communication via text-based medium seems a natural choice for technical personnel, as transferring fragments of these artifacts is both highly ineffective and error-prone via audio-only channels. [PI]

We also found out that many technical personnel considered themselves to have specific, usually introverted, personality traits, which they claimed to affect their preference for text-based communication. As a contrast we also noted that many project managers preferred to use audio-based communication tools. We believe that this reflects both the different nature of the tasks project managers deal with – the tasks are commonly more

unpredictable, involve more problem solving and conflict resolution and are often more urgent, as well as some differences in personal qualities of people in managerial roles in comparison to technical personnel. While we were not able to collect any objective data on personality traits, we are willing to speculate that personality traits do affect both the role one pursues in their career as well as their preference to either text or audio-based communication. [PI]

### 5.2.3 Culture

The effect of culture to communication media choice does depend on both the culture on each site as well as on the cultural distance between the sites.

In one project we studied, cultural distance between Finland and India had caused difficulties in reporting status openly and especially discussing problems in the project. This was due to the two cultures having radically different conventions of communicating negative issues as well as different views on hierarchy and power distance between supervisors and subordinates. The team tried to solve the issues by creating explicit procedures for status reporting and distribution of work. The difference in power distance caused the conventions related to assignment and management of work to differ between sites, even though there was an effort to harmonize these conventions e.g. by using issue tracking systems in a similar way on both sites [PIII].

In another project between Finland and Malaysia, product management had to actively poll the status of tasks and issues frequently from the remote team. Even when Finnish product management team was proactive, they often found out that the remote team in Malaysia had been struggling with the issue for a longer period of time. Similar issues — although to a lesser extent — were found in a project between Finnish and Lithuanian software teams: Lithuanian team members seemed to have a preference to express their concerns and their lack of knowledge less openly when their own superiors were present [PIII].

### 5.2.4 Project and organizational set-up

While most projects had multiple communication media available, many projects had focused on only a few communication tools. This selection for primary communication tools for the project seemed not to be predeter-

mined nor forced by company guidelines or project management, rather than an emergent decision made during the project ramp-up phase or inherited from previous projects, with occasional adaptations during the project execution. [PI] [PII]

In many of the projects studied, team members were working in an open office environment. In open office environments, the noise is often a major cause for distractions. We found out people want to minimize the amount of noise by preferring text-based communication tools over audio-based media, as they did not want to disturb others when they were communicating with remote team members. Team members working in open office environments often chose to do this, even if specific rooms for private telephone calls were available, as the overhead and the interruption cost to work caused by moving to a specific room for ad-hoc, unscheduled meetings or quick questions was simply too high. These rooms were used for scheduled one-to-one phone calls or teleconferencing, though. [PI]

Time difference between sites did constrain the scheduling of teleconferences in some projects. In these projects, team members at one of the sites would have needed to stay at the office beyond regular office hours in order to be able to participate in the meeting. The time difference also limited the maximum length for teleconference meetings. In one of the other projects with no significant time zone difference, the team initially used mainly email to communicate across sites, with occasional team teleconferences. As communication over email became more and more difficult due to the delays of email communication combined with limited availability of key personnel, it started to affect project efficiency. To resolve this, they started to have regular weekly teleconference meetings with the project team as there was no temporal distance between the teams. [PIII]

### **5.2.5 Medium availability and cost**

One of the companies we studied did have specific meeting rooms equipped with video conferencing facilities. These video conferencing rooms were shared between many projects, and thus the rooms were heavily used. The preference to use video conferencing in projects in this company was limited by the high utilization levels of the video conferencing meeting rooms. Team members said it was nearly impossible to use video conferencing rooms for ad-hoc meetings, as the rooms were mostly reserved all the time, and reservations had to be made several days beforehand. [PI]

Using telephones as a communication tool was often hindered by the

cost of international phone calls. While companies generally provided their employees with access to telephones, the extent to which telephones were available varied across projects and sites: typically on-site personnel had mobile phones provided by the company, but off-site people commonly had just one telephone line per team or group. Additionally, in practice the use of telephones was discouraged by companies by cost-reducing policies. [PI] [PII]

#### **5.2.6 Technical constraints**

We found out that in some cases, interviewees were not able to use instant messaging due to technical limitations, e.g. firewall restrictions, from remote locations. This affected their ability to communicate with their preferred tool, and thus they had to use other medium for communication when working remotely [PI]. In another project, however, IM was used to reach people working with multiple networks. In this project, some of the essential services, e.g. issue management system, was only accessible from the customer network, and team members working from different locations had to ask other team members to access issue trackers for them. They used IM to talk with their team members in this case [PV]. In projects crossing organizational boundaries, especially projects involving subcontractors and/or working on customer sites, technical limitations due to security considerations were also affecting communication and media choice: often there are services located both at customer and subcontractor's networks, and project teams would need to access both [PIII].

While typically companies studied did not restrict the communication media choice, they often did have a list of tools approved for projects to use, and other tools were not allowed. Especially for instant messaging they often had a single software all employees were supposed to be used, and use of any other software for messaging was prohibited. This policy was justified by security reasons. Even while this policy was in place, some projects did have other tools in use, either for use in team members located on one site only, or in some cases, even in project team-wide use. [PIV]

5.2.7 Discussion

We found several factors affecting the media choice in globally distributed software development projects. These findings are summarized in Table 5.2. Most notably we found out the effect of language to media choice: low self-conception of foreign language skills lead to preference for text-based medium. As much of the earlier research has focused on homogeneous language groups, we believe this finding to be very useful contribution to the body of knowledge, by helping practitioners to alleviate communication challenges related to language barrier in GSD projects.

**Table 5.2.** Factors Affecting Media Choice in the Projects Studied

Factor	Effect
Language skills	Text-based media "neutralized" the dialect, making the language more comprehensible. Team members with lower proficiency in language preferred written form over speaking
Project role and tasks	People in technical roles felt it was easier and more precise to express technical issues such as source code lines or error messages in written form. Many of them also considered themselves as "introverts" and because of that, the preferred less intrusive means of communication
Culture	Power distance differences in cultures affected how difficult issues were communicated in multi-party versus one-to-one communication media.
Project and organizational setup	In open office environments, team members wanted to minimize the amount of noise by preferring text-based communication tools over audio-based media. Distribution over larger temporal distance limited the use of synchronous communication media.
Medium availability and cost	Use of video conferencing rooms for ad-hoc meetings was limited by their high utilization, as the rooms had to be reserved beforehand. International call cost hindered use of telephones as off-site team had tight budget
Technical constraints	In some projects, certain communication media (e.g. IM, Issue Tracking) was not accessible outside their office or customer network. Organizational boundaries also affected the media choice as some media was restricted to intra-organizational use only.

Another important result is the technical personnel’s tendency to prefer text-based communication media more than non-technical team members. We found out that media choice preferences differ depending on role. In projects studied, people working in more technical roles preferred to use text-based medium, while non-technical team members often preferred to use audio-based communication media. To an extent, we believe this is

related to different tasks these roles need to execute, and thus different requirements for communication media. On the other hand, we found some evidence that allows us to speculate that personality traits may have a role in both how people choose communication media as well as how they pursue their professional careers.

We found out that tools of higher immediacy and symbol variety were useful for building shared understanding within the team, discussing about potentially sensitive issues, and to build and maintain trust and team cohesion. Tools with higher rehearsability were preferred by team members, who considered their language skills to be inadequate, or when discussing about technical, precise and potentially complex issues. Communication media with high reprocessability was used to share information in the project efficiently and effectively, as there were cases in which the information had to be relayed or otherwise processed to another form.

Our results confirm predictions made by MST. Beyond the MST proposition on communication media support for communicative processes, we found out that appropriation factors, especially familiarity with the communication tool itself, familiarity with remote team members as well as the language skills of an individual, do affect both the media choice as well as efficiency and satisfaction on communication over the selected medium.

Earlier research has found the issue of language skills of communicative parties to be related to media choice preference [90, 62], as well as the preference to use different communication media for different parts of requirements engineering process, using text-based medium for requirements elicitation and face-to-face for requirements negotiation [10]. It has also been found out in previous research that different cultures may value media properties differently. For instance, higher uncertainty avoidance seems to imply higher focus on rehearsability and reprocessability properties of the medium [1].

### **5.3 RQ3: Does the choice of communication medium affect team members' satisfaction on communication?**

The experiences on a communication medium use were codified into two categories: performance and satisfaction. The performance of communication medium use is the medium's ability to deliver messages efficiently, and the user's ability to use the medium in an efficient way. The satisfaction on communication medium use manifests itself as a positive attitude



towards the medium, and is typically result from successful communication via the medium, and the ease of use of the medium. [PI]

We found out that in general, communication performance and satisfaction are intertwined. Many interviewees associate positive experiences from a communication medium to both performance and satisfaction. We assume that satisfactory experience with a certain communication tool leads to higher preference towards the medium, which in turn increases the experienced communication performance via learning effect. On the other hand, the assumed or experienced performance of a tool doesn't seem by itself to be enough to change media choice preferences, if the tool does not match personal preferences or satisfy as a communication tool. [PI]

Satisfaction to communication over certain medium seemed to emerge from several factors: ability to reach people through that medium, ability to build understanding of remote context, technical quality of medium, and how well the tool did integrate into their work flow. Following sections will present our findings for each of these factors.

### **5.3.1 Ability to reach people via the medium**

In order to communication to be successful, one must be able to reach relevant parties over the chosen medium. In many cases, this requires certain "critical mass" adoption for the tool, as well as frequent use of the tool by those who need to be reached.

A common challenge when using email as the primary communication medium was its asynchronicity: it was often difficult to get answers to questions in time, especially when other team members were busy working on their own work items. IM delivers messages near simultaneously in comparison with the often minutes-long technical latency of email, not to mention additional delay of even days before recipients actually reply to their emails. IM was preferred for urgent communication, mostly because its ability to deliver messages quickly, and because it also provided presence awareness. Most IM users were satisfied with its ability to deliver messages quickly, and thus they preferred to use it to get answers quickly to short and simple questions. [PIV] [PII]

Many team members liked presence awareness functionality in IM tools. Many interviewees were using IM to check availability of their colleagues for communication, regardless they intended to use instant messaging or some other medium. The presence awareness allowed them to assess

whether immediate response could be anticipated, or if they should seek other sources of information in order to complete their task. Many interviewees attributed this as a very useful feature, removing idle waiting and thus increasing the performance of their communication. Instant messaging was also considered an efficient tool for communicating across teams, as one could participate in one or more discussions at once, while resuming other activities at the same time. [PI] [PIII]

Similar results have been reported in other studies as well [34], where IM acts "as a real time glue between different channels".

In some projects, team members considered the pace of instant messaging to be too high. They felt that instant messaging required them to respond immediately. This feeling may have caused them to prefer other tools that could provide them more time to think and formulate their message. Even though the IM tools provide cues for presence, the expectations of immediate responses when using instant messaging can cause tensions. When people are busy, they seldom have the possibility to communicate, even though the tool could provide the means for quick interaction. [PIV]

As noted by many interviewees, the immediacy of feedback is low with email; it can often take more than one workday to get a reply sent via email. Symbol variety is also low, as with other text-based media. As emotions, gestures and facial expressions are unavailable, it is difficult to understand the context of the remote team members, and to evaluate whether they were available for communication or busy working on other issues. However, as email is an asynchronous communication medium, it allows high level of parallelism — other tasks can be completed while waiting for a reply to an email message — and it allows communicative parties to structure and refine their messages, i.e. allowing sender to rehearse the message. Email was also used as a substitute for a document repository, which shows the high level of reprocessability it provides as a communication tool. [PII]

### **5.3.2 Ability to build understanding of remote context**

In one of the projects studied, the team regularly spent some time in the beginning of the team's weekly audio conference meeting for non-work related social issues. In practice, team members were invited to share non-work related experiences, to share with others what they had done during the previous week or what plans they had for the week ahead. This was found especially useful in building understanding on the differ-

ent cultures present in the team, and to provide additional information about the particular working context and environment on the remote site. However, extra care must be taken so that such informal and non-work related parts of the meeting do not take too much time, as this kind of informal socialization was considered inefficient by some team members. [PII]

Instant messaging was also to gain some insights about the context on the remote site, and to build awareness of the presence and availability of remote team members, especially when they were not successful in receiving timely responses over email [PII]. Other studies have also seen IM as a strong medium to provide "means to build trust and social relationships with co-workers" [34].

We found out that telephone as a medium had often negative connotations amongst the people we interviewed. We believe one possible source of dissatisfaction with telephone communication may have resulted from the topics discussed in the telephone calls, as projects often resorted to use one-to-one telephone calls in cases of urgent issues and project failures [PI]. As the context of telephone calls were often negative, this may have had a negative effect on the overall attitude towards the medium itself. The issues discussed over phone calls were often ambiguous, equivocal and uncertain, and managing concepts with such properties often require both time and effort. Many interviewees acknowledged that there are issues that are hard to deal with using text-based media, and as such they were satisfied with the availability of an audio-based tool to solve these issues. They chose telephone as a medium for communication, because even though they acknowledged it was more difficult to understand what was being said, the synchronicity of the medium allowed them to ask for clarifications more easily, and the additional auditive cues provided by the medium let them hear whether the recipient has misunderstood them or not. [PII]

### 5.3.3 Technical quality

In many projects studied, the main challenge in audio conferencing was poor sound quality [PII]. The poor quality made it difficult for the participants to understand what was being said, especially when working with team members whose English skills were less than perfect, or when there was a mix of different English dialects or pronunciations [PII] [PIII]. In many cases, poor sound quality combined with different dialects and lan-

guage skill levels seemed to render some meetings with audio conferencing nearly useless [PII].

Poor audio quality and difficulty to understand what was being said due to foreign accents did not always stop project teams from using teleconferencing. In one of the project studied, the team did choose to use teleconferencing even if it was more difficult to understand what was being said. The synchronicity of teleconference allowed them to ask for clarifications more easily, and when they were able to hear the other participants, they were able to immediately know if the recipient has misunderstood them or not. The ability to build understanding more quickly was more important for the team than apparent difficulties in using the communication medium [PI]

The main benefit of video conferencing is the additional cues it adds to the communication. When properly set up, video conferencing allows all participants to see the facial expressions of others, which helps in evaluating whether communication is successful, whether the message has been understood or whether further explanations and discussions are needed. The live video image also allows the participants to see who is in fact talking at the moment, something that can be challenging when working with new people and over lower quality telephone lines. [PII]

#### **5.3.4 Integration to work flow**

IM tools often use auditive and visual alerting to notify users on communication activity, such as incoming messages or other users logging in to the system. In some cases, these alerts were considered as distracting to their work flow, and hence an annoying feature of the IM tool. Due to large number and frequency of alerts, some team members chose to close the IM tool when they were particularly busy with their tasks, and needed to concentrate. In some projects, the flow of instant messages may even have turned into an overwhelming flood of messages for some team members in software projects. Sometimes one person could act as a proxy or a filter for the incoming questions, thus allowing the other person to concentrate on her work better. [PIV] [PII]

Many team members considered using the telephone very intrusive and interruptive to the work. This was due to both the psychological need to answer any call immediately as well as the lack of multitasking ability for the telephone as a medium; telephone conversations often require such a large share of constant attention that working on other tasks simulta-

neously is impossible [PII]. As an alternative, IM was considered more polite, as it allows more parallelism and does not necessarily interrupt the work immediately. For this reason, it was considered easier to initiate communication over IM. It was noted, that the possibility to multitask can cause loss focus and make people feel anxious and frustrated, especially if the amount of communication requests becomes too high. This may reduce the likelihood IM is used, or at least cause delays in answering the questions as people occasionally may turn IM tools off [PV].

Some projects have integrated their issue management and IM systems, allowing team members to instantly be informed of any issues assigned to them. While integration with other communication tools was generally seen as a positive thing, it sometimes caused confusion about what tools should be used for further communication on the issue and how discussions conducted outside the issue management system should be documented. [PII]

In some of the studied projects, it was quite common that the IM discussions were not actively saved. This lack of trace was often used as an argument against the use of instant messaging. In some cases, people stored the conversation logs on their own workstations. The main purpose for saving the logs seemed to be to keep some kind of evidence of the decisions made through IM. This has been used especially to provide some backup in cases where conflicts may surface later between the communicating parties. [PIV]

### **5.3.5 Discussion**

We found four main factors affecting to satisfaction in communication: ability to reach people through that medium, ability to build understanding of remote context, technical quality of medium, and how well the tool did integrate into their work flow. The main effects of these factors to communication satisfaction are listed in Table 5.3.

**Table 5.3.** Factors Affecting Communication Satisfaction in the Projects Studied

Factor	Effect
Ability to reach people via the medium	Asynchronous communication introduces delays, which causes dissatisfaction. IM presence status can help assess if someone is available for communication now, improving satisfaction as communication success can be anticipated
Ability to build understanding of remote context	Synchronous media, and especially teleconferencing, was found useful in informal, non-work related discussion, which helped to close the cultural gap between sites, improving overall satisfaction to communication as shared understanding and cohesion was increased. Telephone calls were useful to resolving urgent issues quickly, and allowed to clarify complex issues faster
Technical quality	Many audio conferencing systems had poor audio quality, which decreased the satisfaction to communication over that medium. However, similar to telephone calls, despite the poor technical quality, the synchronicity of communication made communication more efficient.
Integration to work flow	Informants had mixed feelings about interruptiveness of IM to their work flow. Some considered it annoying to be interrupted by IM messages, but the possibility to ask questions rather easily and with low overhead was considered helpful. Cross-medium integration of work flows, for instance IM and issue tracking, was found useful, while sometimes confusion arise which communication medium should be used for further communication

When working in a distributed setting, it is important to make sure the communication tools are compatible with the project and the team, both technically and socially. This includes the harmonization of the tools' technical aspects, i.e. using compatible versions as well as open, reliable and secure infrastructure, e.g. proper configuration of firewalls, so that tools can be used at all sites or even remotely, if needed. Additionally, the tool usability and accessibility is important: in many cases the high initiation costs of video conferencing was inhibiting its use, while on the other hand IM was preferred, as it was readily available at all times.

Social compatibility of communication and collaboration tools includes a common agreement and definition on how the tools should be used, e.g. commitment from all team members to answer to emails in due time, or being logged in to instant messaging whenever available for communication. The common agreement on communication practices is also important, e.g. when deciding who should be present in which meetings, where to store important decisions, and whether to inform the whole team about decisions made privately, for example, in instant messaging discussions.

Earlier research has reported similar findings to some extent: media familiarity, availability of medium and "infrastructure capabilities" have been found to be significant drivers for media choice, as well as personal preferences, team and company policies and communication media availability [80, 27, 60, 61].

We found evidence of perceived inefficiency and dissatisfaction to communication when media choice was in disagreement with suggestions by MST. As an example, using asynchronous medium, such as email, to communicate urgent issues caused dissatisfaction and inefficiency, as inherent delays — often workdays, in case of temporal distribution and when contacting busy team members — were caused by the asynchronous nature of email.

We also found, that multiple communication tools are useful for GSD teams, as their tasks are versatile and often complex, thus requiring support for both conveying information and converging understanding. Therefore, as an answer to research question 3, we claim the ideas presented in MST seem to be useful for media choice in GSD project, and that MST seems to be applicable to GSD projects.

Previous research has identified media choice to have an effect on communication satisfaction and individual participation level [41]. Earlier research has also reported the importance of both availability of other team members via the tool as well as specifically being able to be aware of other peoples' availability through the medium [66, 30, 52, 93].

#### **5.4 RQ4: Can proper communication media choice improve the perceived efficiency and effectiveness of communication in GSD teams?**

Fourth goal of this thesis was to investigate if a connection between communication media choice and perceived communication efficiency and effectiveness does exist. We found out that the perceived efficiency and effectiveness of a communication media arises from six factors: the perceived formality and support for structure in the medium, immediacy of feedback, ability to multitask, support for additional cues, ability to reach other people using the medium, and ability to save the communication for later review. In the following chapters, we investigate our findings on each of these factors.

#### 5.4.1 Media formality and support for structured communication

Many interviewees reported instant messaging (IM) being a very efficient tool for communication in global software projects. One part of the experienced efficiency of IM seems to be related to its informality in comparison to email. Messages communicated via instant messaging are short and interdependent, making it possible to both read and write them quickly. Email messages, on the other hand, tend to be more self-contained. The experienced informality of IM makes it possible to neglect some of the text-based communication etiquette, such as spelling or grammar, both further lowering the overhead associated with the use of that communication tool, and increasing the informal nature of the medium. [PI]

There are several aspects of email, which were thought to make it more efficient than IM. One email message typically contains considerably more information than a single message in an instant messaging session, and thus the volume of emails is typically much lower than the message flow in instant messaging discussion of same information value. The lower number of distinct messages, and higher capacity of single message reduces the absolute amount of distractions during the communication session, and thus reduces the disturbance caused due to communication to other work processes. Email messages are often complete, stand-alone entities than single messages or even whole conversations in IM, thus making it possible to share the discussion with other people, simply by forwarding the email message to them. This aspect of completeness means there is less need to explain the context of the communication when using emails compared to other communication media. Lastly, many interviewees regarded emails more formal as a medium — and therefore more suitable than IM discussions — for more persistent storage in issue tracker or document repository. [PI] [PII]

[PI]

We have also found that using video conferencing makes meetings more structured, and the basic meeting practices are more carefully abided by than is the case with audio-only teleconferences. People tend to be more focused on the meeting, and less occupied with other tasks, which may often be problematic in teleconferences. This particular effect of video conferencing arises from the stronger social presence this medium provides, i.e. during the meeting, people have a stronger sense of togetherness when



communicating by videoconference than when doing so by teleconference. [PII]

For developers focusing on quality assurance, the issue tracker can easily become the main communication channel with the team. While communicating about issues related to software quality — e.g. announcing new bugs or keeping track of the status of fixes — can be efficiently done via the issue tracker, in many cases multiple communication channels are called for. The use of a single communication medium, especially the use of the relatively lean and asynchronous issue tracker, may disconnect team members mainly relying on these tools from other team members, and introduce undesired isolation within the team, which can manifest itself as unawareness of the overall situation and context of the project. [PII]

As such, issue tracker is a communication medium, which provides a high level of reprocessability, as the main function of such repository is to provide information for which future actions can be based on. Issue trackers also aim at providing more symbol variety via specific structure of the issue record, and potential file attachments — such as screenshots or example data — related to the issue. Issue tracker tools also allow users to revisit and edit the issues they have reported, thus providing high level of rehearsability. Immediacy of feedback depends on the specifics of the issue tracker system, e.g. how new issues or changes in issue states are reported to stakeholders. [PII]

#### **5.4.2 Immediacy of feedback**

Immediacy of message delivery with IM tools and the convention to keep it always open facilitates communication between remote team members, and thus enabled the whole project team to share information more efficiently and with lower communication initiation costs [PV]. IM tools do not impose long delays between messages, and thus they allow fast exchange of information between the communicating parties [PIV] [PI]. This property was exploited by the practitioners, allowing them to ask questions and know that they are going to be answered in a timely manner [PIV] [PI]. It seems that it also dictated the contents of the messages somewhat, in the sense that mostly short and simple queries are exchanged through the medium [PIV] [PI].

Audio conferencing provides immediate feedback on communication: a question will receive some answer immediately. Symbol variety is also

higher than with text-based media, as tone of voice can be used to emphasize important issues, or to provide other additional cues on the discussed subject. Parallelism of audio conferencing is often low, as verbal communication often requires nearly full attention from its participants. The interactive nature of audio conferencing makes it difficult to rehearse the message beforehand, but recorded meetings and meeting minutes — while adding more overhead into arranging a meeting — from audio conferences may help to increase the reprocessability. [PII]

Perceived importance and urgency of the message is a factor when selecting a media for communication [PI]. For instance, one-to-one telephone calls were found to be an especially efficient way of communicating urgent issues requiring immediate action, while for non-urgent matters phone calls were often considered to be less efficient [PII]. In case the communication need was urgent, both technical and non-technical personnel preferred to use audio-based communication medium, most commonly telephone [PI]. In most projects studied, the use of telephones was limited to urgent issues, and thus we believe this convention increased people's responsiveness to telephone calls, as well as increased the perceived efficiency of the medium [PI].

### 5.4.3 Multitasking capability

Instant messaging allows other activities to be conducted while still available and engaged in communication. This allows communicative parties to perform their primary tasks, but still support remote team members. This was claimed to increase performance and productivity [PV]. Multitasking ability of IM was often used also in meetings, both co-located and distributed. In such meetings, it was difficult to call over phone with people outside the meeting while still attending the meeting itself, without severely disturbing the flow of the meeting. IM was used as a way to get answers to questions during the meeting, or to communicate issues discussed during the meeting, without affecting the ongoing meeting too much [PIV]. In addition to personal IM use, in some projects IM was used as a side channel during the meetings [PIV]. It was found efficient medium for sharing detailed technical information, such as error messages, as communicating them otherwise could have been slower, and more prone to errors and misinterpretation [PIV].

The ability to multitask with IM was considered both positive and negative, depending on the context. On the positive side of using IM during

meetings, it allowed meeting participants to ask questions from others not participating the meeting, which increased the efficiency of meeting [PIV]. People not participating the meeting were also able to reach people in meetings over IM while they could still be engaged in other activities [PV]. With IM, this was possible, as the medium is asynchronous enough to allow people to wait for answers from people attending meetings at the same time [PV]. On the other hand, in meetings with more IM activity from outside, some people had to divert their focus from the meeting to discuss on other issues over IM, thus reducing the efficiency of the meeting [PIV].

We found that one-to-one telephone calls were seldom regarded as effective in the sense of communication performance. In addition to its interruptiveness to work flow, the lack of multitasking ability for the telephone as a medium contributed to this assessment. Telephone conversations often require constant attention, and thus working on other tasks simultaneously is nearly impossible. [PII]

#### **5.4.4 Ability to reach people using medium**

Many team members, especially managers, had a lot of meetings, and were often unavailable [PIV] [PII]. We noted that instant messaging was a popular way of communicating with such busy people. [PIV]. Telephone was also used as a tool to contact people who were often too busy to be reachable through other media [PII]

The projects studied utilized project-wide mailing lists, which were used to share important issues with all team members at once. Such use of email was considered useful, as long as the number of messages sent was low enough for team members to actually keep track of the messages. Another benefit from using mailing lists was that each team member then had a copy of important announcements and decisions, and had the ability to retrieve this information from their mailboxes when needed. Another practice many of the teams studied used was to send the transcripts of important IM discussions to the whole team. The experiences of this practice were mostly positive in the teams using it, as it combined both the flexibility and synchronicity of IM and the asynchronicity and reachability of email. [PII]

IM tools allowed easily switch between one-to-one communication mode and many-to-many communication by adding more people into the text chat session or to the conference call. This functionality was commonly

used to gather information from specialists (e.g. asking a specific question from an architect during a session between two developers), or to problem solving with a group of colleagues. Many interviewees utilized the flexibility of instant messaging to manage communication sessions between one-to-one and many-to-many communication modes. [PI]

Reprocessability makes IM a good tool for agreeing on and sharing technical details: exact text format ensures that information is not lost or distorted during the communication, and that it can be easily retrieved. This was found important when working with remote team members: having "evidence" of discussions and ability to review the conversations later was made possible by high level of reprocessability. [PV]

Email messages are more often complete, stand-alone entities than single messages or even whole conversations in IM, which often would need some context and structure to be easily reusable and distributable with others. On the other hand, many team members found email messages to be easily shareable with other people, as there was less need to explain the context of the communication. Sharing information by simply forwarding emails to other team members was seen more efficient, as they were able to communicate the desired aspects more carefully and comprehensibly, and with less effort. [PI]

#### **5.4.5 Additional cues**

We found out that people preferred to use text-based medium for tasks of low equivocality and high certainty, such as status reporting and task assignment. On the other hand, many interviewees reported that they prefer to discuss new ideas or more complex concepts over telephone, to make sure the other people have understood it. [PI]

Chat over IM is text-based medium, and thus does not convey many non-verbal cues, being limited to punctuation and use of smileys or emoticons. Based on our findings, the lack of symbol variety seldom seems to be an issue when using IM, but indirectly we found out that use of text chat can take more effort and can sometimes be frustrating. However, the symbol set provided by text chat was found more suitable in sharing technical information, often as a side channel during meetings [PV]

Additional cues were found useful when using issue trackers. When reporting a potential problem or a bug in the software, it was found useful to be able to include a document or link visualizing the issue in addition to textual description of the problem. Some teams had a practice of con-

stantly adding step-by-step screenshots to describe how a certain issue could be reproduced. The ability to augment bug reports with screenshots did increase perceived efficiency of communicating the issues to other team members, especially by developers who were assigned the responsibility to fix the issue. [PII]

We found out that telephone calls were seldom attributed to be effective in the sense of communication performance. This may have resulted from the topics covered in telephone calls. The issues discussed over phone calls were often ambiguous, equivocal and uncertain, and managing concepts with such properties often require both time and effort. Many interviewees acknowledged, that these issues are hard or impossible to deal using text-based media, and as such they were satisfied with the availability of audio-based tool to solve these issues. Only in urgent or emergency situations were performance and telephone calls commonly related to each other. [PI]

Desktop sharing was used in meetings, and it was found to increase the efficiency and reduce misunderstandings, when all meeting participants were able to see what was on the screen of the presenter. Beyond its use in meetings, desktop sharing was used for demonstration purposes in one of the projects studied. The desktop sharing technology enabled team members to demonstrate the functionality of the software to customer remotely, without the need to meet face-to-face or to train on-site personnel on the demonstrated features. Another use for desktop sharing was remote training of new team members. Desktop sharing was found useful also for problem solving and when working together with a remote pair. [PII]

#### **5.4.6 Ability to store and review communication**

Synchronous tools generally suffer from the transient nature of the communication contents: once conversation is over, the contents either disappear or are stored in a way that is difficult and/or time consuming to replay and review [PV]. It was seen important to be able to communicate significant decisions made in collaboration with the customer to the relevant team members [PI]. In some projects, there was a strong intention to record these decisions immediately by capturing them in textual form, typically by using email as a communication tool: in practice this often meant emailing meeting minutes or memos to all project team members [PI]. In some projects, this extended to a practice of using email

as a substitute for a document repository, which shows the high level of reprocessability it provides as a communication tool [PII].

While in most project such decisions were made in either face-to-face setting, or via audio or video conferencing, the need to immediately and precisely communicate these issues to other parties not present at the meeting existed. Thus, whenever a change was requested by the customer, or any significant decision was made, an email was sent to those who were stakeholders for the decision – typically including at least the customer, the project manager and occasionally also other team members. [PI]

For messages considered to be important, many interviewees preferred to use a communication medium, which leaves trace of the communication. The most commonly available tool to fulfill this requirement was email, while some projects had also conventions of storing the most important instant messaging discussions. Many projects were also utilizing issue and task tracking systems to capture important messages and decisions, and these systems were used then as the authoritative source and repository for important and significant decisions, especially for technical decisions. [PI]

In some projects, IM conversations were routinely saved, and the conversation logs were published in other information systems used in the project, such as in a task management tool or in an issue tracking system. This practice was considered useful, as it enabled later review of both the discussion, and possible decisions on the issue. Sometimes it seemed to be difficult for team members to identify when the transcripts should be saved and shared with others. The nature, seriousness and content of conversation can change rapidly, and it can be difficult to know it in the beginning of the conversation whether the conversation should be logged or not. [PIV]

IM tools are still focused on individual level, each user having their own application and account in the IM system. Thus, even if the tool supports saving the logs, the copy of conversation log is personal, and generally accessible only to the communicative parties. Projects studied had various approaches in solving this problem, depending on the respective team structures, responsibilities, and other communication tools and project repositories available. [PV]

#### **5.4.7 Discussion**

We found six factors affecting how communication efficiency and effectiveness was perceived in the projects studied. Main findings for each factor are summarized in Table 5.4.

**Table 5.4.** Factors Affecting Perceived Communication Efficiency and Effectiveness in the Projects Studied

Factor	Effect
Formality and support for structure in the medium	IM is more informal, and allows for relaxed spelling or grammar, lowering the overhead of communication. On the other hand, email messages are more self-contained, and thus understandable per se without the need to understand the context of communication. Issue Tracking provides structured format, which make it even more efficient to convey information, as long as it fits the structure allowed by the medium.
Immediacy of feedback	IM was perceived as efficient communication medium as it was possible to anticipate quick response to questions through it. Limiting a communication medium only for urgent matters improves its perceived efficiency, as communication over that specific medium then carries a special "stigma", as was the case with telephone communication in the project studied.
Ability to reach other people using the medium	It was possible to reach otherwise busy people using IM, and this made communication with busy team members more efficient at least to team members trying to contact them. Mailing lists were also considered efficient communication, as long as the overall number of messages sent through mailing lists was kept low enough so that it would not overload anyone.
Ability to multitask	IM allowed team members to continue perform their primary tasks, but still support remote team members; this was considered efficient and to increase overall performance. IM was used during meetings to ask questions from non-participants outside the meeting, which was considered useful, but meeting participants also received messages during meetings, which was considered less useful and harmful to the meeting itself due to distraction of focus. Inability to perform other tasks while in telephone calls was one of the reasons why telephone calls were not considered efficient.
Support for additional cues	Lack of additional cues in text-based media made team members consider it less efficient in cases when complex issues needed to be communicated over the medium, while teleconferencing and especially videoconferencing was preferred in those cases — as it was possible to infer from the additional cues if the message was understood. Additional structure provided by issue trackers, such as links to external documents, could be considered as additional cues, since it extended the expressiveness of that medium, and made it easier to share information and understanding on the issue. Desktop sharing also increased the symbol set of teleconferencing, by providing a shared view for all communicative parties, increasing the perceived efficiency of the medium.
Ability to save the communication for later review	IM transcripts of important IM discussions were sent to mailing lists, so that that information could reach people who were not part of that particular IM session; challenge being that unless logging was enabled for all IM discussions, it was difficult to determine beforehand whether an IM session should be logged for later use or not. Some projects used email as a simplified, ad-hoc replacement for document repository.



Our results indicate, that if tool use and media choice was aligned with the propositions by MST (see 2.4.3 and [22]), communication was usually found both efficient and effective, while in cases where the media choice was suboptimal according to MST, the communicative parties did notice at least some inconvenience: they were either frustrated in the delays and inaccuracies in the replies they received, or in the inefficiency of communication. While we have no objective performance or satisfaction measures from the projects, we argue that choosing communication tools for GSD against the recommendations by MST cause the communication to be both inefficient and dissatisfying for project teams.

As an example, we found a connection between successful projects and successful instant messaging use. Often the primary purpose for IM was to ask quick and simple questions from other team members — a communication task requiring mostly conveyance — communicative parties did benefit from high parallelism (i.e. being able to continue to work on their main tasks), but at the same time quick enough feedback so that they could get their answers in short enough time. We believe that another key factor for successful instant messaging tool use in GSD projects is the mutual agreement and commitment of all team members to using the tool regularly.

However, we think that the successful use of instant messaging in global distributed projects requires exploiting multiple features of the tool rather than using it for only single purpose. As an example, discussing complex topics often required using more synchronous tools. We also found that especially new teams did benefit from sharing more of the remote sites' context, which is easier and more convenient when using a synchronous tool such as audio or video conferencing, while more established teams did find less synchronous communication tools adequate. These findings are also aligned with MST proposition on established groups and accepted social norms reducing the need to highly synchronous medium.

One communication medium or tool is often suitable only for a limited set of tasks and activities: MST suggests that a single tool can be good at supporting either convergence or conveyance processes, but not both. As suggested by MST, we found it important to have a comprehensive selection of communication tools available for GSD teams to use, in order to cover the various communication and collaboration needs of a GSD team. The availability and utilization of multiple communication tools within a team is necessary also to meet the differing preferences and working

practices of individual team members, and to allow the establishment of efficient and effective communication practices and information sharing within and beyond the team.

There is support for MST in earlier research on connection between successful projects and media choice being aligned with MST [36, 27, 32, 63, 10, 11], similar with our findings.



## 6. Limitations

This section contains a summary of the main limitations and threats to the validity of this research.

### 6.1 Internal Validity

Internal validity refers to the extent to which the findings accurately describe reality [38]. In order to increase the likelihood our findings match with the reality, we used two different triangulation approaches: data triangulation and theory triangulation.

Data triangulation was based on using multiple separate, independent case projects for collecting data. We studied twelve software projects from three software companies. By using multiple case projects, we wanted to eliminate the possibility for our findings to be dependant on the particular project and company context. While the number of projects studied is still fairly small, the variability in context of these projects seemed adequate for understanding the media choice and use in given context. It should be however noted, that the selection of the case companies and project was purposeful — our study was focused on software projects having one of their sites in Finland — and this may have biased our results. Most of the interviewed team members had European cultural backgrounds. While it is possible that cultural background itself may influence both the selection and the use of communication tools, we have no significant evidence supporting any systematic bias this.

For data analysis, we used multiple different approaches at various stages. Initially, we started with exploratory coding of the interview transcripts, with the intention to generate theory by identifying salient phenomena in media choice and use. For the second stage, codification was redone with code set based on MST, thus contributing into theory triangu-

lation. We also evaluated the results against multiple different theories, including MST, Media Richness Theory and Social Presence theory.

As the presented results are based on qualitative analysis of semi-structured interviews, validation and verification of the results by triangulation and combining several data sources and methods, such as analysing the actual communication by quantitative methods, would be beneficial, and may help to strengthen the conclusions. Specifically quantitative study on actual tool use and subjective evaluations and preferences on tool suitability for specific tasks would provide further insights into tool use in GSD projects. We aimed to verify some of our findings by collecting actual communication data and analysing the communication patterns with social network analysis tools, but we were not able to do this for the whole dataset and for all our findings. The lack of quantitative results therefore is a limitation of this research.

## 6.2 External Validity

External validity refers to the extent to which the findings can be generalized beyond the studied contexts [38]. We studied twelve distributed software projects in this study from three different companies. While in general, the aim of qualitative research is not to create generalisable results, but to generate theory, we wanted to include multiple, independent projects from different companies, in order to maximize the number of separate project contexts. By increasing the number of different contexts as well as understanding of each of the specific contexts, generalisability of the results may be increased.

While we tried to get as diverse contexts for the projects as possible, the contexts of projects studied were similar in some respect (e.g. cultural background, geographical location). While we do believe that this has only minor effects, and thus results could be applied to other contexts as well, these facts are true limitations and may affect the generalisability of the findings. Furthermore, the sampling of case organizations was based mainly on both convenience and accessibility through research cooperation. The selection of individuals for interviews and observations was guided by the research design, but the practical availability of people at the companies affected the selection. Furthermore, for one case project, we were not able to interview the onsite team members, which limits our understanding of that particular project.

One threat to external validity of our results arises from the fact that data collection has been done in 2007 - 2010, nearly 10 years before the publication of this thesis. However, based on the results from more recent studies, we believe our findings are still valid, thus rendering this threat to a minor one, although one that readers should keep in mind when applying the results in more recent contexts.

### 6.3 Reliability

Reliability threats refer to the inability to replicate or reproduce the results in another, subsequent study. As by definition, software projects are unique, it is indeed impossible to reach the exact same results in another study. As the data was collected via semi-structured interviews, the persona of the interviewer as well as interviewee, as well as the context of the interview session do affect the data collected. While we aimed to ask the questions in similar way and not to lead interviewees in any direction, this is a natural limitation for reliability for any research using the same data collection method. As we used data collected from previous interviews to guide the subsequent interview sessions, it is also obvious that we did not ask all interviewees the same questions, but were able to infer background information from previous interview sessions. However, we did try to do our best not to reveal or leak any insights or opinions of other interviewees during these sessions, thus allowing each interviewee to describe the topics in their own words and without any comparison to previous interviews, thus eliminating any dependencies between the ordering of the interviews.

First pass of qualitative analysis was performed by multiple researchers. We have evaluated and discussed the consistency of our codification process, but we haven't explicitly assessed the inter-rater agreement between our codifications of the transcripts. While this might affect parts of the analysis, we believe the actual effect to the final results to be negligible, as it is limited only to the thematic codification of interviews. While this type of analysis is highly dependent on the researcher performing the analysis, theory triangulation, more specifically the use predefined set of codes further increase the likelihood of other researchers being able to extract similar findings and to draw similar conclusions on the data. All interviews were recorded and transcribed, and the transcripts are archived, and thus the analysis can be redone by other researchers.

## 6.4 Construct Validity

Construct validity is related to the operationalization of the theoretical concepts in an empirical study, i.e., how well the measured data represents the theory and concepts under study. In this study, the threats to construct validity arise from both the methodological and theoretical aspects.

Firstly, it can be argued whether qualitative study, especially one that is focused on interviews, is adequate and appropriate in order to collect data on communication media choice and use in software projects. The threat to validity arises from the potential difference in articulated and actual media choice and use. We did not observe the media use in any but one of the studied projects, and even in this one project we focused only on email and IM use. Therefore, we are limited by the accuracy of interview answers by the participants, and have no sense whether their answers accurately represent the truth. However, we have no reason to believe there would be any systematic bias in this affecting our results significantly, beyond the inherent inability to quantitatively measure and compare the results across different cases. For instance, while we were initially worried about interviewees reporting only official communication tool use (i.e. only the use of company-approved and sponsored communication media), in many cases we did get information of unofficial, ad-hoc communication methods and tools set up by individual team members or organizations. Especially when some of these communication methods were explicitly forbidden by their employers, we are confident that interviewees were able to be open and honest about their communication patterns and behavior, even if it contradicted what was considered right and acceptable for them.

Secondly, as we were partly evaluating the phenomena based on specific theories, our constructs were biased towards the concepts provided by those theories. This would have been a limitation of the study, if it were the only basis for the data analysis, or if we would have used the theory-based model first and applied grounded theory after that, but in fact we believe we were able to decrease the extent of "theory pollution" in our grounded theory approach by applying it first, and only becoming aware of the applicable theories after the codification of the data was already made. Therefore, as the grounded theory approach did reveal some of the similar concepts as theory-based codification, we are confident that

the constructs used in this research seem to be reasonably valid for the scope of this research.

Lastly, as one major part of this research was to provide insights of the applicability of a specific theory (MST) in the context of GSD, using the constructs of MST for analysing the data do make sense, even if we would assume those constructs to be invalid. As we did find some evidence from the data to support the theory, one contribution of this research is also further validation of the MST constructs.

## **6.5 Evaluating results based on original MST versus revised version of MST**

In some of the included research articles [PI], [PII], [PIII] we used the original version of MST to construct the theoretical framework to analyse the results and to benchmark against. The differences between the two versions of MST are described in more detail in Chapter 2.6. In this section, we aim to evaluate the effects of using the original version instead of the revised version in data analysis and interpretation.

In most cases in our analysis, we have either used an interpretation of the original version of MST which encompasses the subtle corrections introduced in the revised version. For instance, for our analysis, we have tried to separate the potential a communication medium has for immediate feedback and actualized communication speed separate. As an example of potentially differing interpretations on the data with the two versions would be how social behavior is taken into consideration: while video conferencing potentially allows rapid feedback, it is not in fact utilized, if people are not able or willing to provide open and timely answers over the medium. In our opinion, we have done an effort to keep the two separated in our analysis, thus mitigating the risk of confusion as well as the difference in interpretation between the versions of MST.

Similarly, the changes in definitions of parallelism and symbol sets are, in our interpretation, more related to the comparison of medium potential versus actualized medium use. As we have based our analysis into inquiry based on actualized medium use, such change in viewpoint does not mean any non-trivial change in the way our results would be presented.

The revised version does introduce additional concepts, most notably appropriation factors, to the framework. Appropriation factors include aspects of actualized medium use, such as familiarity, availability and



easiness of use, some of which we were able to discover in our study, and thus present some evidence of usefulness of MST into studying and understanding media choice processes in globally distributed software teams.

As a summary, while we acknowledge the subtle differences between MST revisions, we consider the usage of original version in analysis to be at most a minor limitation in the study considering the nature and methodology used to analyse the data and results.

## 7. Conclusions

The following chapters provide the answer to the research problem, and draw the theoretical and practical implications of the studies presented in this thesis, followed by the aspects future research should address in the field of communication tool use in globally distributed software projects.

### 7.1 Research Problem: How is communication media chosen in globally distributed software projects?

As we discussed in the answer for the first research question, globally distributed software projects do have many communication media at their disposal. The organizations studied built their communication media mix on top of three main communication media: email, instant messaging and teleconferencing, with some projects further augmenting the communication media mix with auxiliary communication media, such as issue trackers and document management, or expanding the capabilities of one of the core three tools, usually replacing teleconferencing with video conferencing.

We argue, based on our findings, that the selection of the strong three tools as the core of communication media mix was driven by their popularity and familiarity of use of these tools, especially in the case of email and teleconferencing. When we reflect the media properties to MST, we also notice, that these three tools do differ in terms of media synchronicity: email being extremely asynchronous and teleconferencing almost the opposite — while instant messaging lies in between, in a gray area of near-synchronous communication media. In terms of MST predictions, this does seem to make sense. MST recommends the use of multiple communication media, as any non-trivial task would require both communicative processes — convergence and conveyance — and while no single

communication medium could support both optimally.

Across the projects studied, the media choice for a specific purpose did however differ. Most notably temporal distance did limit the use of synchronous and near-synchronous communication media in some projects, as it was simply impossible to communicate with remote team members in different time zones at all times. Also personal skills, most specifically technical vs. non-technical role as well as language skills, did affect the media choice: team members in technical roles and with less proficiency in spoken language did prefer to use text-based medium — email or instant messaging — more than non-technical team members or those who felt they had adequate language skills. These findings are aligned with MST predictions as exchanging detailed technical information benefits from reprocessability and rehearsability allows senders to review their message for spelling mistakes and clarity before sending it to others, thus increasing communication efficiency and satisfaction.

Based on our findings, communication media choice does affect globally distributed software projects. The effect media choice has on GSD projects is two-fold. Media choice can expose overall problems within the team and project in such way that they manifest themselves as mostly communication challenges. On the other hand, media choice can be also used to alleviate project and organizational impediments, even before they are manifested as organizational problems.

An example of overall project challenge that was manifested firstly as a communication problem is the distribution of roles and responsibility. Many of the project studied initially had a strict distinction between "head" and "body" of the project: on-site team often acted as the brains of the project while off-site was merely expected to execute on the instructions and specifications given to them by the on-site team. In many cases, it was initially believed that such division of tasks is efficient and easy, and that off-site team would be able to execute and implement the tasks on-site team gave them, without the need of extensive communication — thus relying on asynchronous communication media, such as email and issue trackers. Those projects usually soon realized that asynchronous media was not able to handle the communication need between different sites — and more specifically, between different functions — of the project team. We saw multiple cases that teams had to resort to regular cross-site meetings and also to one-to-one synchronous communication beyond those meetings to address the communication need and thus resolve the

work distribution problem they were facing. Furthermore, as synchronous communication increased cohesion and trust between on-site and off-site teams, the responsibilities and distribution of work roles was often more intertwined. In practice, off-site team was gaining more responsibility and autonomy in their tasks, while on-site team was even more focused in supporting the off-site team instead of merely instructing and supervising their work.

As an example of how media choice does alleviate organizational challenges in GSD projects is the use of asynchronous or near-synchronous media which allows a greater deal of rehearsability than real-time, synchronous communication, and how it helped to empower and engage off-site team members. The specific challenge in one of the project studied seemed to be how to engage remote team members in meetings. They were often passive during weekly teleconferences, and seemed to only reply when asked directly, but not contributing to overall discussion. The main reason for remaining passive during meetings was related to remote team members' self-reported lack of confidence in their language skills. The ability to rehearse and revisit their communication before sending it to others — when using asynchronous or near-synchronous tools, such as email and instant messenger — improved their ability to engage in discussions with on-site team members, and to express their concerns. Finally, the increase of overall communication and especially now established ability to spontaneous communication with team members from other site did contribute to trust building across sites and thus increased cohesion within the project team. By simply choosing the appropriate communication media based on the context, skill set and preferences did help alleviate not only communication challenges, but the overall efficiency and performance of the whole project team. It can be further assumed, that being able to address such communication challenges early on in the project life cycle did aid the project to achieve its goals, both in terms of quality and quantity.

To answer the research problem, the effect of media choice in GSD project extends beyond immediate and obvious communication challenges. The choice of medium is crucial in both single, individual interactions between team members, but will also alter the nature of team work in the project overall. The factors which affect media choice in GSD project in practice do not rise only from the properties and capabilities of a communication medium, but also personal factors and preferences as well as organiza-

tional context do play a considerable role. A suboptimal medium from MST perspective may in practice fare better, if it suits organizational needs better, if it is more approachable, available and easier-to-use than the optimal medium, and if it solves specific communication issues that may be theoretically minor but practically significant to some of the team members. We found evidence supporting MST, and suggest that MST is very useful framework to evaluate, assess and plan communication media choice in GSD projects. At the same time, we noticed, that in specific use cases, media choice derived from MST could lead to lower communication satisfaction, efficiency and effectiveness in a globally distributed software project. Therefore, it is important to use MST as a general framework, and carefully analyse any remaining communication challenge a project is facing.

## 7.2 Theoretical implications

Our main theoretical contribution is related to further confirming MST as a valid theory, and solidifying the available evidence for validity of MST in understanding communication media choice in globally distributed software projects.

Firstly, we believe our results and presentation of our analysis helps to identify which parts of the theory are applicable for any globally distributed software project. Based on our results, the effects of communication media choice in immediacy of feedback and parallelism are crucial and often manifested in many if not all GSD projects, while other factors, such as the need for rehearsability and reprocessability, as well as the other factors, such as language skills and cultural differences in power distance, will require additional considerations and understanding of the project context, team and organizational structure as well as cultural aspects.

Secondly, we found out that as predicted by Media Synchronicity Theory, both communication processes — conveyance and convergence — are always present and required in GSD projects. The need for both processes arises from the fact building software is a complex task, and thus requires both sharing of information and building mutual understanding. Furthermore, this is reflected in the media mix of GSD projects, as there is no single communication medium that can support both convergence and conveyance well, thus requiring GSD projects to use multiple communi-

cation tools.

Thirdly, we believe we were able to highlight some aspects of media choice processes which were missing from the original MST version, such as the appropriate use of communication media, availability of communication media, as well as the importance of giving all team members options and some freedom of choice when choosing communication media. Such additional observations are of use when applying the framework into understanding and analysing new, emerging communication media.

While the methodology used in this thesis is mostly qualitative, and thus the approach is not to necessarily measure and verify the results concisely, we believe that the findings, discussion and conclusions of this thesis do contribute to the existing body of knowledge.

### 7.3 Practical implications

The main practical implication from our research, we can advice practitioners to utilize MST as a framework when evaluating and choosing communication media for GSD projects.

As partical implications, we found out several factors affecting media choice and communication performance in globally distributed software teams.

Most notably, the effect of language skills do have an effect on which communication media is preferred, to communication clarity, efficiency and satisfaction, and ultimately to project success. Especially low self-assessment of foreign language skills seem to drive team members to use text-based media instead of audio-based media, as text-based media has higher rehearsability and reprocessability, both important for non-native speakers of a language in supporting their ability to produce and consume foreign language.

We also found out that the type of task and professional role affects the tool preference. While managers prefer higher synchronicity, developers seem to prefer higher parallelism and reprocessability in their media choice. Our understanding is that this is simply due to their different goals in communication: managers are often contacting developers to find out status of an issue or to seek clarification about a single detail, while developers need to understand the product being developed more holistically and in greater precision.

In addition to different role preferences, the tasks do differ, and thus

tools supporting both convergence and conveyance are always needed in globally distributed software projects. We found out that in many cases multiple communication media could be used to complete a single task, clearly indicating the need for both communicative processes to accomplish a single task. The practical implication of this means each GSD project should have multiple communication media available, some with high and some with low synchronicity.

Lastly, we have presented multiple minor implementation notes and advice, such as question about volatileness of IM transcripts and traceability of communications throughout the project, which we believe will be useful for any practitioner implementing or reviewing the communication tool set of their GSD projects.

## 7.4 Future work

The results of this thesis do call for more research in this field in the future.

While our results indicate support for MST, we also identified many areas which cannot be easily connected to MST propositions. We hope to see more research on especially the effect of language skills in media choice preference. Furthermore, future research should investigate the relationship between successful media choice in GSD projects and the success of establishing efficient communication practices. The specific requirements different communication practices as well as different software development paradigms and processes have on communication media should be explored as well. We also believe that different communication media can provide support to different teams and project contexts. Further research about specific project team compositions and their communication media choice could reveal more insights about scalability and efficiency of specific communication media in different project contexts.

Communication tools evolve over time, and new communication media become available. Future research in this area should study the effects of these new communication tools, such as microblogging services and collaborative text editing, in more detail, and evaluate their role and benefits for distributed software development, especially given the time span of the data collection for our research. Also convergence and consolidation of communication media into single toolset seems to be interesting, as this would reduce the overhead cost to switch between different com-

munication media, as well as automatically share information between different communication media and tools, e.g. providing presence awareness to email service. We believe that MST is useful in studying emerging tools in GSD context.

The connection between communication media choice and choice of software development methodology and practices is also a very interesting topic for future research. We believe that different ways of organizing software project work, including the use of agile and lean methodologies as well as different models of project organization and team structures, affect communication needs in GSD projects, and may reveal different challenges and focus areas for communication media choice and media mix planning. Furthermore, studying communication needs between technical software development project teams with business teams and other stakeholders, including customers, most likely will reveal new aspects and factors to communication media choice.

Finally, we believe MST could be used to guide tool development. By exploring the media capability space tool developers could find gaps in their toolsets' support for communicative processes. In addition to improving and enhancing existing communication tools, this could even lead to the development of new communication tools and media for globally distributed software teams.





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